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ABSTRACT

Statistics on the allotment of funds and descriptions of activities carried out under the auspices of the National Science Foundation (NSF) in 1973 are reported. Details are provided for activities in the categories of: (1) research project support, (2) national and international programs, (3) research applications, (4) science education research and programs, and (5) science resources and policy studies. Among the appendices are a listing of staff, advisory committee, and panel members; details of organization changes and appointments; a financial report for 1973; a description of patents resulting from NSF-supported activities; a publications list; and a list of national research centers' contractors. (BB)

ED 093664

National Science Foundation Annual Report 1973

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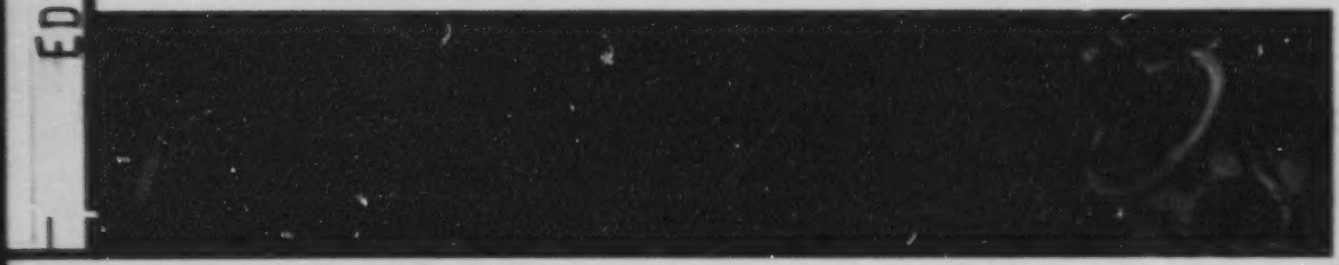

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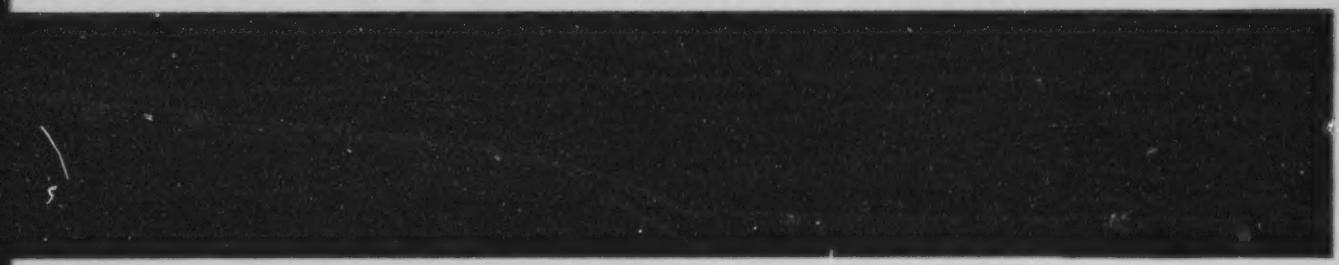

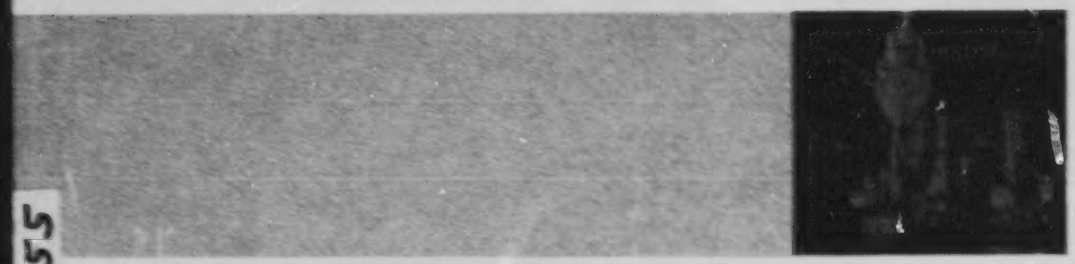

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Letter of Transmittal

Washington, D.C.

DEAR MR. PRESIDENT:

I have the honor to transmit herewith the Annual Report for Fiscal Year 1973 of the National Science Foundation for submission to the Congress as required by the National Science Foundation Act of 1950.

Respectfully,

H. GUYFORD STEVER
Director, National Science Foundation.

The Honorable
The President of the United States

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Director's Statement

An annual report is usually thought of as a record of activities—an accounting of a stewardship. This report is no exception, but it also reveals something about science and the viewpoints of those charged with responsibilities for the work of the Foundation. One of the things revealed by some highlights from this year's Annual Report is how science goes about probing the unknown. For instance, one important way to go beyond the current limits of human experience and understanding is to find out what actually happens in natural systems in order to determine how they work. Tracing the pathways followed by natural materials or organisms often makes it possible to identify uniformities, quantify relationships, make valid predictions, or carry out other scientific activities. But determining the sequence of natural events can be very difficult.

Research Project Support

A good example is chemical reactions in solutions. While such reactions are extremely common, most chemists have underestimated the influence of the solvent while concentrating on the chemical properties of the molecules directly involved in the reactions. Now, we are finding that the solvents are much more important than realized before, and in some instances it appears that almost all of the energy needed to make reactions take place is involved in getting the solvent out from between reacting molecules. Several new lines of evidence illuminate this sequence, and one technique now makes it possible to sort out complex reaction chains and, equally important, to tell when charged particles of a given mass are not involved in a given reaction.

Research in the biological sciences also illustrates the importance of accurately determining the sequence of natural events. Some strategies to regulate pest populations may use cultivation practices to influence the life cycle pathways of harmful organisms. If soybean plants are planted so that there is a continuous canopy at the time of flowering, it has now been established that a certain pathogenic fungus flourishes because of the higher humidity. This fungus attacks a serious soybean pest known as *Heliothis*—as it hatches and before it can destroy the blossoms.

At times, pathways can be exceedingly subtle and complex and take sustained effort and long periods of time to elucidate, as in the case of photosynthesis, which converts solar energy into plant growth. The green pigment chlorophyll is an essential ingredient of this process, and as long ago as the 1930's it was concluded that molecules of chlorophyll must act cooperatively rather than individually in this energy conversion. But major aspects of the associated reactions were not clarified until recently. This research delineated two plant photosystems with different properties occurring together. One system ultimately makes available the energy needed by the cell, but does not generate oxygen or fix carbon dioxide. The other system evolves oxygen and reduces carbon dioxide to form carbohydrates, but does not have an energy function. Both pathways are complex, but work together in making the plant organism viable.

All of the natural processes just described have one important characteristic in common—they exist now and man is not the operative mechanism. But sometimes we are interested in pathways that might exist by man's intervention and can be shaped according to our future needs or resources. Alternative pathways for the environment are particularly difficult to delineate because of their complexity. Recognizing this, a group of scientists has created a dynamic environmental simulator that will enable people to "walk" or "drive" through small, three-dimensional scale models of urban, suburban, and natural environments. These simulated tours through miniature environments will provide vivid and accurate previews of alternative environments of value to planning and to public decisionmaking.

National and Special Research Programs

While many independent investigations spread out over a period of time may be the best way to determine some complex pathways, some others yield more readily to many-faceted attacks done in concert. In an effort to learn how

the tundra ecosystem functions, for example, dozens of scientists from different institutions converge on Point Barrow, Alaska, and other sites, to do intensive research during the short summer arctic growing season. Results, when analyzed and compared, then can suggest what particular research emphases may be most beneficial in successive summers.

The Foundation is also supporting work to understand the vast oceanic mixing processes and other physical, chemical, and biological studies related to the transport of pollutants in the ocean and their effects on marine life. To do this, in part, trace elements and radioisotopic data are used to establish geochemical baselines for quantitative studies of ocean mixing and for developing improved models of ocean circulation.

And some kinds of pathways, like those revealing the Earth's and the universe's history, are best detected using specialized sampling and observing facilities—like the deep sea drilling ship *Glomar Challenger* or a large astronomical telescope at one of the national research centers supported by the Foundation—that are shared by many scientists.

These examples illustrate only a part of a part of science. They stand, also, for only a portion of the work supported by the NSF in its efforts to foster scientific research about nature and its laws. The Foundation seeks to maintain a national scientific capability in all fields of science. To do this during fiscal year 1973, the NSF obligated $420 million, or almost 70 percent of its funds, for Scientific Research Project Support, National and Special Research Programs, and National Research Centers. This represented an increase of $46 million over the previous fiscal year.

Research Applications

Just as there are many different ways to probe the unknown, scientists have different intentions when they embark on their explorations. For some, application is less important than understanding. Others have a particular application for which they are aiming, as in the case of the Foundation's Research Applied to National Needs (RANN) Program. In this program, more so than in our general programs of scientific research, specific attention is directed toward problems of national importance with the objective of contributing to their practical solution. In so doing, efforts are undertaken to shorten the lead time between our basic research activities and more highly structured development programs of other Federal agencies or other users.

In pursuit of these objectives, the RANN program obligated almost $70 million during fiscal year 1973. This amounted to about 12 percent of the total funds obligated by NSF. With these funds, emphasis has been placed on definite systems concepts involving energy, the environment, and productivity.

The need to expand the availability of the Nation's energy resources needs no further description here. An important aspect of this problem relates to the development of alternative forms of energy and the technology base for their practical use. For example, new optical coatings to trap solar energy have been improved by a factor of two. Research activities on environmental issues include efforts to improve our ability to manage the environment effectively and alleviate threats to the natural environment such as trace contaminants. Improved productivity in the private and public sectors of the Nation is needed to stimulate economic progress and to assure that the increasing sums devoted to public services are spent efficiently. Applying research to these needs may take the form of studying manufacturing processes or examining new technologies and systems which could improve city and State performance in the delivery of selected public services.

R&D Incentives and Assessment

The latter activities of the RANN Program are of interest to the Foundation's Experimental R&D Incentives Program, which was still in the planning stage at this time last year. The objectives of this new program are to encourage the innovation of new technological products, processes, and services into both the private and public sectors of the civilian economy and thus to encourage non-Federal investment in R&D activities. During fiscal year 1973, over 600 proposals were received and reviewed, and 69 awards were made amounting to over $11.8 million. The awards were divided among planning, support, and background studies; project experiment design and definition awards;

and exploratory test experiments, which was the largest category, amounting to about two-thirds of the dollar value of the total awards. In the first year of operation, 57 percent of the award obligations were made to private sector areas and 43 percent to public sector areas. We believe that we are off to a good start to develop knowledge by experimentation which will help lower and eliminate barriers to innovation and technology transfer in the public and private sectors of the civilian economy.

The National R&D Assessment Program is another new program started in fiscal year 1973. Through this program, analysis is made of patterns of research and development and technological innovation, the factors that underlie the existing patterns, and the implications that a choice of options will have in shaping future patterns of research and development and technological innovation. With the commitment of $2 million of program funds, work was undertaken on such diverse subjects as a review of our state of knowledge of the effect of patent and antitrust laws and regulations on innovations, the dynamics of international transfer of technology, social and private returns from technical innovation, diffusion of technology, and what past studies of innovation processes add up to.

Science Education

During the first part of fiscal year 1973, NSF completed an extensive examination of its science education efforts. Out of that examination came a restatement of science education objectives, which now are to:

- improve education for careers in science, with greater participation of minorities and women;
- improve science education to meet the needs of a broader range of students and foster science training for the nonscientist; and
- increase the effectiveness of science education through improved programs, applications of technology, and improved instructional strategies and methods.

Efforts to improve education for careers in science are addressed to maintaining the quality of training in the traditional science disciplines as well as to the development of new instructional patterns which can lead to a diversity of scientific and technological career options for people ranging from secondary school graduates to graduate degree holders.

Because it has become increasingly important for everyone, whether or not they are engaged in science- and technology-based occupations, to be able to comprehend the use of the methodology and results of scientific discovery and technological development in their work and personal lives, the Foundation is continuing to improve education to increase scientific and technical literacy. This is done through the development of materials and teaching strategies that can be matched to the learning abilities of both the theoretically inclined student who learns rapidly from the printed page and the more practically oriented student who learns best from "hands-on" materials and tangible models.

At the same time that a broader range of teaching techniques and materials is being developed, efforts are being more sharply focused on dissemination of information and the training of teachers and resource personnel to help in the implementation of the new materials and techniques.

Because the rising costs of education are of concern to everyone, we are attempting to develop, over the long run, more cost-effective teaching modes, selected technological devices and systems, and the effective use of technical aids to teaching. The NSF, in order to help stem the rising costs of education, has focused both on applications of technology and improved organization and management of the educational enterprise. For example, delivery systems are being developed and tested that permit student self-pacing, that allow learning units to be readily adapted to the capabilities of the student, and that make it possible for students to move in and out of the educational system in line with a student's changing career goals and financial resources.

Specific NSF Objectives for the Near Future

In this brief statement, it is impossible to summarize all of the activities which the Foundation supported or carried out during fiscal year 1973. The selected highlights which I have presented are only indicative, but they do provide some clue of what we have done in fiscal

year 1973, and some future directions. In a sense, they constitute markers on the pathways which the NSF is following. But we are also interested, of course, in why the Foundation carries out its various programs.

We continue to adhere, over the long range, to our traditional emphasis of advancing scientific knowledge through fundamental research across the spectrum of the sciences. In addition, we try to emphasize both basic and applied research to help efforts to resolve selected national problems.

Guided by those fundamental goals, the Foundation has also identified and committed itself to meeting a number of agency objectives that appear to be realizable in the near future. While these represent only a few of NSF's many research aims, they show the kinds of areas in which NSF is now active.

I. *Initiate development of the most advanced radio astronomy "array" to increase the potential for breakthrough in man's understanding of the universe and its origin and evolution.*

The astronomical community has selected as its highest priority for new facilities the development and construction of an advanced radio telescope which will greatly improve the resolution of radio astronomy observations and should contribute to our fundamental knowledge about the nature of energy and matter.

II. *Develop options and recommendations for the future role of NSF in the funding of science.*

The technological society in which we live is placing ever-increasing demands on science for new knowledge and on technology for the application of that knowledge to achieve national objectives. In order to obtain maximum benefit from Federal resources in this area, it is necessary to understand the Federal role in science and to identify those efforts that promise the most rapid scientific and technological advancement.

III. *Contribute to the improvement of the U.S. capability to assess the resources of the oceans.*

The rate at which the Nation's mineral, petroleum, food, and other resources are being consumed makes it essential that accurate assessments be made of the ocean's potential for meeting many of man's future resource requirements.

IV. *Improve capability to control harmful insect pests through biological techniques.*

Heavy reliance on DDT and other synthetic pesticides since World War II has significantly lessened insect problems but is causing environmental pollution by chemical residues which may act adversely in several ways against nontarget organisms, including the natural enemies of insects, and in some cases man. The NSF is supporting research on the corn earworm and other insects with the objective of finding practical biochemical or ecological regulation strategies for their control.

V. *Improve the Nation's capability to design and construct earthquake-resistant structures.*

Over $10 billion annually is spent on construction in high earthquake risk areas, such as California and Alaska, and it is of national economic concern to improve the capability to design and construct earthquake-resistant structures.

VI. *Improve the Nation's capability for suppressing severe hailstorms.*

Another natural hazard, hailstorms, causes an estimated $300 million annual loss to American farmers. The NSF is supporting research to provide sufficient understanding of the mechanisms of hail formation to determine if damaging hailstorms can be suppressed.

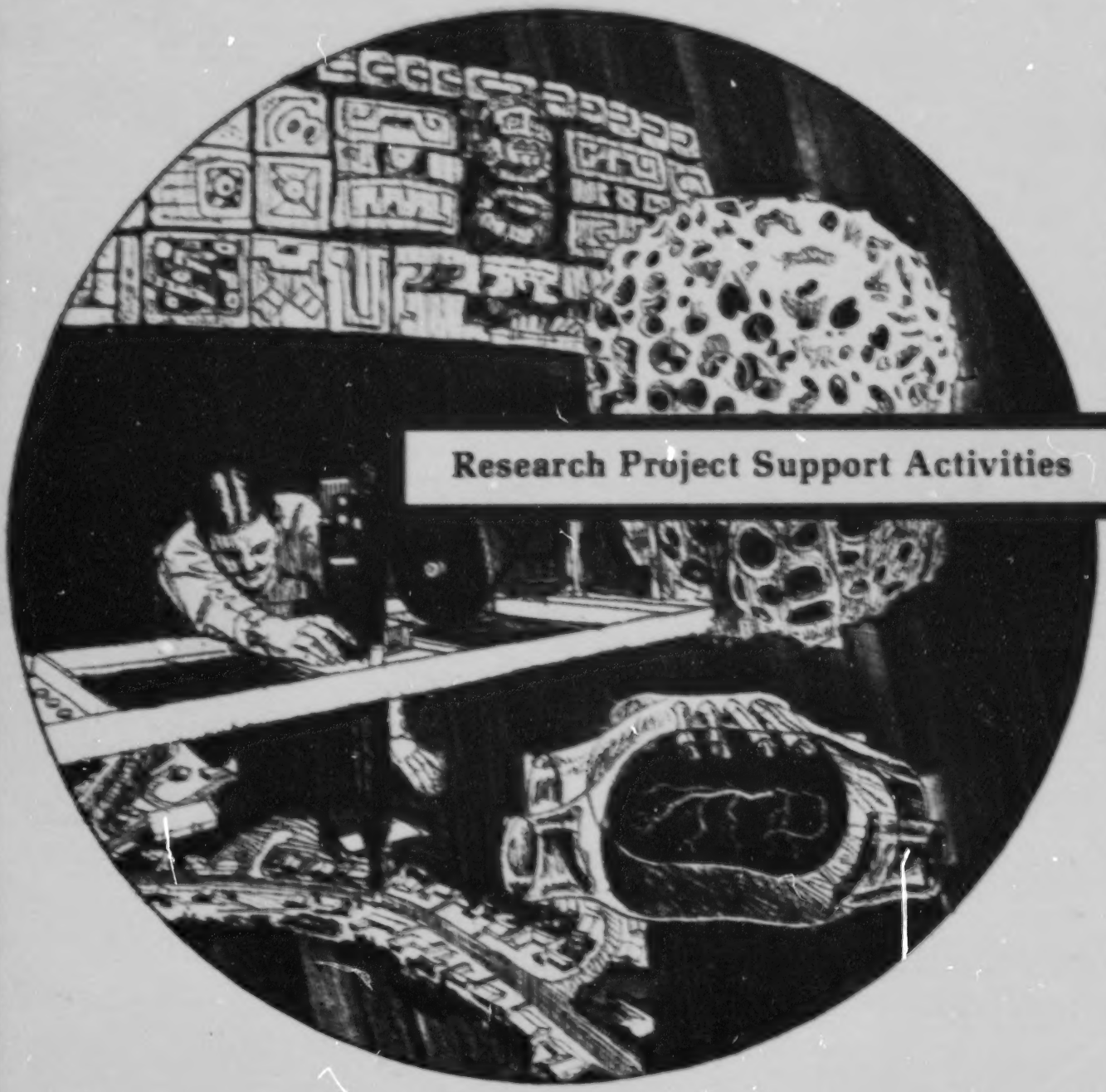
VII. *Develop practical application of solar energy to the heating and cooling of buildings.*

As a part of the national effort to develop new sources of energy, the NSF has been given the lead agency role for developing techniques for the practical application of solar energy. Currently, about 25 percent of the Nation's total energy consumption is for heating and cooling buildings. The increasing cost and shortages of "conventional" energy sources makes development of new energy sources a high priority national concern.

VIII. *Support the development of the technology needed to locate, develop, and manage geothermal sources and to economically generate power from these sources.*

Although it has been estimated that the geothermal energy reserves for the United States exceed the hydroelectric power resources, relatively little utilization or development of this energy source or its associated technologies has been made. NSF is supporting work to locate and characterize geothermal sources of all kinds and to develop methods for the economic utilization of this energy.

It is important to emphasize again that the objectives and activities mentioned above represent only a part of the total framework of the Foundation. These objectives have the full support of the President and will represent a significant focus of agency attention and effort. The progress we make towards their achievement will be reflected in future reports to the Nation.



Research Project Support Activities

Research Project Support Activities

The support of research is the principal activity of the National Science Foundation. Its major program for this purpose is Scientific Research Project Support, managed by the Research Directorate through more than 70 program offices organized by scientific discipline. Research is supported in essentially all fields of the environmental, physical, life, and social sciences, as well as in mathematics and engineering. In fiscal year 1972 slightly more than 14,000 proposals were received by this program, nearly all from academic institutions where support affords graduate students an opportunity for research experience under the direction of leading scientists as a byproduct of the quest for new scientific knowledge. Essentially all proposals for Scientific Research Project Support are unsolicited. They are reviewed and evaluated by active researchers in the field represented, as well as by Foundation staff. On the average, 3 to 5 reviewers are called upon to comment on a particular proposal; in the course of a year between 18,000 and 20,000 different reviewers, serving without compensation, are called upon to assist in this process, which culminates in a recommendation for action by the Foundation's program officer. In some disciplines, proposals may also be reviewed by assembled panels, and certain proposals are reviewed by the National Science Board. In selecting proposals for support, the Foundation seeks out those of highest scientific merit, evaluating such factors as the relationship of the proposed work to the state of knowledge in the field, the probability that the research will contribute significantly to the field, the soundness of the research plan, and the qualifications of the investigator to successfully carry it out. The final recommendation for support depends upon the availability of funds allocated to that particular field. In making its distribution by field within the project support program, the Foundation considers the dynamics and trends in support by other funding sources of each field and the relative readiness of the different areas of research to move ahead. Thus, within its appropriations for research project support, the Foundation allots its funds so as to maintain a balance of research activity on a national scale between the various disciplines and, at the same time, to provide a continuity of effort within them to assure a viable base of research capability.

In fiscal year 1973, the Foundation awarded 6,138 grants amounting to $268.0 million for the support of individual research projects. Comparable figures for fiscal year 1972 were 5,800 grants for a total of $248.6 million. The distribution, number, and amount of grants according to field of science for fiscal years 1971, 1972, and 1973 are shown in Table 1. Grants were awarded to 465 institutions, including 332 colleges and universities, in all 50 States, the District of Columbia, and Puerto Rico; 93 percent of the funds went to academic institutions. Of these, 226 received 2 or more research grants, and 129 received $200,000 or more. Table 2 shows the average distribution in fiscal year 1973 for approved cost items on the 6,138 research grants.

Several organizational events took place in fiscal year 1973 which affect the program activities of the Research Directorate. The support of specialized research facilities and equipment was integrated into the regular scientific research project program and is no longer identifiable as a separate allocation of funds. However, support for research equipment has been maintained; when the special allotments in former years are combined with funds made available for permanent equipment on regular research grants, the total amount obligated for this purpose from project support funds in fiscal years 1971, 1972, and 1973 was $15.9 million, $19.9 million, and $20.3 million, respectively. A second event of importance was the transfer to the Research Directorate of the research programs of the Office of Computing Activities. Also in fiscal year 1973, the Advisory Committees for Mathematical and Physical Sciences, Biological and Medical Sciences, Social Sciences, Environmental Sciences, and Engineering were merged in a single Advisory Committee for Research. The new committee met for the first time in March and has undertaken several studies relating to problems of administering Foundation research support programs.

The following text discusses some highlights of recent research supported by the Research Directorate. Also included in this chapter are scientific highlights of activities of the National Research Centers and the Office of Computing Activities. Activities under the two national programs administered by the Research Directorate—the International Biological Program and the Global Atmospheric Research Program—are covered in a later chapter with other national programs.

Table 1
Scientific Research Projects
Fiscal Years 1971, 1972, 1973
(Dollars in millions)

	Fiscal year 1971		Fiscal year 1972		Fiscal year 1973	
	Number	Amount	Number	Amount	Number	Amount
Astronomy						
Solar System Astronomy		$ .45		$ .50		$ .60
Stars and Stellar Evolution		1.59		1.87		2.20
Stellar Systems & Nebulae		.52		.57		.50
Galactic & Extragalactic						
Astronomy		3.07		4.02		4.50
Astronomical Instrumentation and						
Development		.94		.95		.80
Subtotal	138	6.67	135	8.01	170	8.80
Atmospheric Sciences						
Aeronomy		2.30		2.23		2.92
Meteorology		4.73		9.[illegible]		9.68
Solar Terrestrial		2.37		[illegible]		3.32
Subtotal	248	9.40	218	[illegible]	232	12.92
Biological Sciences						
Cellular Biology		8.92		11.98		11.90
Ecology & Systematic Biology		8.86		10.28		12.42
Molecular Biology		10.02		12.05		12.50
Physiological Processes		8.89		10.63		10.92
Microbiology		4.05		4.47		4.46
Psychobiology		3.60		4.07		4.02
Subtotal	1,394	44.34	1,444	54.[illegible]	1,584	56.22
Chemistry						
Synthetic Chemistry		4.27		5.17		5.14
Structural Chemistry		3.11		3.71		3.60
Quantum Chemistry		3.54		4.15		4.02
Chemical Dynamics		3.50		4.37		4.76
Chemical Analysis		2.06		2.98		2.63
Chemical Thermodynamics		2.39		2.64		2.57
Chemical Instrumentation		1.70		1.89		1.38
Subtotal	548	20.57	603	24.52	675	25.08
Earth Sciences						
Geology		1.64		1.74		1.95
Geochemistry		3.05		3.79		3.86
Geophysics		3.43		3.91		3.95
Subtotal	327	8.12	[illegible]	9.[illegible]	298	9.76
Engineering						
Engineering Chemistry and						
Energetics		5.83		8.57		8.42
Engineering Materials		6.98		——		——
Engineering Mechanics		9.77		10.17		10.30
Electrical Sciences &						
Analysis		1.48		6.89		7.44
Special Engineering		1.02		—0—		—0—
Subtotal	695	25.10	865	25.63	865	26.16
Physics						
Elementary Particle Physics		11.90		13.74		13.90
Intermediate Energy Physics		—0—		—0—		1.80
Nuclear Physics		9.42		11.27		8.80
Atomic, Molecular & Plasma						
Physics		2.75		3.32		3.70
Theoretical Physics		2.72		3.79		3.60
Solid State & Low Temperature						
Physics		5.72		——		——
Astronomical Physics		—0—		1.25		1.40
National Magnet Laboratory		40		——		——
Subtotal	599	32.61	271	33.38	298	34.40
Social Sciences						
Anthropology		3.56		3.85		3.84
Economics		4.56		5.21		5.46
Sociology, Social Psychology						
& Social Indicators		4.57		6.39		6.14
Political Science, Law &						
Social Science		1.46		2.39		2.62
Special Projects, Geography,						
History and Philosophy of						
Science		3.51		4.61		5.18
Science Policy Research		——		——		.20
Subtotal	690	17.66	819	22.45	835	23.63

Table 1—Continued
Scientific Research Projects
Fiscal Years 1971, 1972, 1973
(Dollars in millions)

	Fiscal year 1971		Fiscal year 1972		Fiscal year 1973	
	Number	Amount	Number	Amount	Number	Amount
Materials Research:[1]						
Engineering Materials		—		6.50		6.79
Solid State and Low Temperature Physics		—		9.66		9.76
Ionic, Solid Chemistry and Polymer Science		—		2.87		2.88
Materials Research Laboratories		—		12.00		13.11
National Magnet Laboratory		—		2.75		2.50
Synchrotron Radiation Facility		—		—		.75
Subtotal	—	—	982	33.59	405	36.97
Mathematical Sciences:						
Chemical Analysis & Chemistry		2.23		2.91		3.10
Modern Analysis & Probability		2.56		2.62		2.67
Algebra		2.66		2.98		2.78
Topology & Foundations		2.22		2.27		2.22
Applied Mathematics and Statistics		3.07		3.27		3.31
Special Projects		.50		—0—		—0—
Subtotal	535	12.83	681	13.75	752	14.08
Oceanography:						
Physical and Chemical Oceanography		2.69		4.01		4.06
Submarine Geology and Geophysics		3.35		4.15		4.33
Biological Oceanography		3.88		4.39		4.27
Subtotal	236	9.92	273	12.55	287	12.66
Computing Activities:[2]						
Computer Science & Engineering						6.32
Computer Applications in Research						3.25
Special Projects						.33
Subtotal					161	9.90
Total	4,661	$190.37	5,800	$240.57	6,138	$260.35

[1] Included under Materials Research for FY 1972 and FY 1973.
[2] Included under programs in Chemistry, Engineering, and Physics in FY 1971 at a total of $11.36 million.
[3] Included in National and Special Research Programs for FY 1971 and FY 1972.

Table 2
Scientific Research Projects, Average Distribution of Funds by Type of Expenditures for Fiscal Years 1971, 1972, and 1973

	Fiscal year 1971		Fiscal year 1972		Fiscal year 1973	
	Amount	Percent of total	Amount	Percent of total	Amount	Percent of total
Professional Personnel						
Faculty	$ 6,580	15.0	$ 6,194	14.1	$ 6,506	14.9
Research Associates	2,668	6.1	2,987	6.8	3,342	7.7
Research Assistants	5,510	12.6	4,877	11.1	5,124	11.7
Other Professional	2,274	5.2	2,065	4.7	1,916	4.4
Total Professional Personnel	17,012	38.9	16,123	36.7	16,888	38.7
Other Personnel	3,499	8.0	3,383	7.7	3,342	7.6
Fringe Benefits	1,618	3.7	1,757	4.0	1,961	4.5
Total Salaries and Wages	22,129	50.6	21,263	48.4	22,191	50.8
Permanent Equipment	2,756	6.3	2,724	6.2	2,451	5.6
Expendable Equipment and Supplies	3,149	7.2	2,900	6.6	3,253	7.4
Travel	1,396	3.1	1,319	3.0	1,337	3.1
Publication and Printing	612	1.4	615	1.4	668	1.5
Computing Costs	1,396	3.1	1,186	2.7	1,114	2.6
Other Costs	2,536	5.8	3,778	8.6	1,918	4.4
Total Direct Costs	33,894	77.5	33,784	76.9	32,932	75.4
Indirect Costs	9,840	22.5	10,148	23.1	10,739	24.6
Total Average Grant	$43,734	100.0	$43,932	100.0	$43,671	100.0

MATHEMATICAL AND PHYSICAL SCIENCES

The Mathematical and Physical Sciences encompass areas fundamental to those more applied sciences that attempt to explain man's environment or facilitate his utilization of its resources. Often, the extension of the basic knowledge acquired in these areas of physics, astronomy, chemistry, and mathematics requires years to reach a state where an end product satisfies one of man's practical needs or contributes to his physical, mental, or aesthetic well-being.

Within the past several years, a number of other governmental agencies and private sources have channeled their resources to scientific work that more directly applies to specific practical goals. Accordingly, their support of the more fundamental sciences has decreased, resulting in the Foundation's assumption of a larger fraction of the support of these areas. Funds have been made available to the Foundation to support some, though not all, of this research. Still another pressure on research funds is the increased sophistication in instrumentation and techniques required for the current research milieu, which raises the cost of projects. As a result, the Foundation has necessarily become more selective in its choice of projects in the mathematical and physical sciences and has been unable to support many additional promising investigations for which it has been approached for sponsorship.

Experimental or observational science inherently requires instrumentation, and increased complexity of such equipment makes possible in a number of ways progress which would not be otherwise achieved. Small computers used as adjuncts to other equipment, for example, for acquisition or preliminary processing of data increase profoundly the number of experiments for which the instrument might be used. Accordingly, over half of the funds provided in chemistry for the instrumentation program during fiscal year 1973 were used for acquisition of equipment involving such small computers.

In some cases advances in instrumentation make possible experimentation which could otherwise just not be done. Several examples are given on these pages. In chemistry, a new instrumental technique made possible the study of reactions independent of the effects of solvents. Previously the need to first place the molecules in solution led to a masking by the solvent of the true tendencies of the reacting molecules. In physics research, the study of extreme energy proton-proton reactions could only have been carried on at the CERN Intersecting Storage Rings.

Instrumentation incorporating relatively new developments has also increased the precision in studies of previously known phenomena. Special electronics circuitry at the National Astronomy and Ionosphere Center has given more detailed information on pulsars, and new electronic scanning and data storage systems at Lick Observatory permit order-of-magnitude increases in observing efficiency with a telescope at the same time that precision is also increased. A new laser technique at the University of Rochester permits highly resolved time studies of photoelectric emission, supporting Einstein's theory of 1905.

Not being an observational or experimental science, mathematics does not share this dependence on instrumentation for progress. Like those other sciences, however, mathematics experiences successive advances related to underlying knowledge acquired during earlier periods of time. An example is given here, where after relatively dormant intervals of 30 or 40 years, significant steps forward led to a buildup of momentum, and considerable progress is now being made toward the solution of a number of problems of interest in several disciplines.

PHYSICS

Secondary Particle Production Excess at CERN-ISR

One of the most perplexing of questions in all of particle physics is that of the structure of the proton and neutron. Whereas the electron can be considered to be a pointlike particle, the nucleon is known to have a size of the order of 10^{-13} cm. Speculations and theories based upon the idea of pointlike constituents (partons) for the nucleon have resulted from experiments on particle resonances and very inelastic scattering of electrons from nucleons.

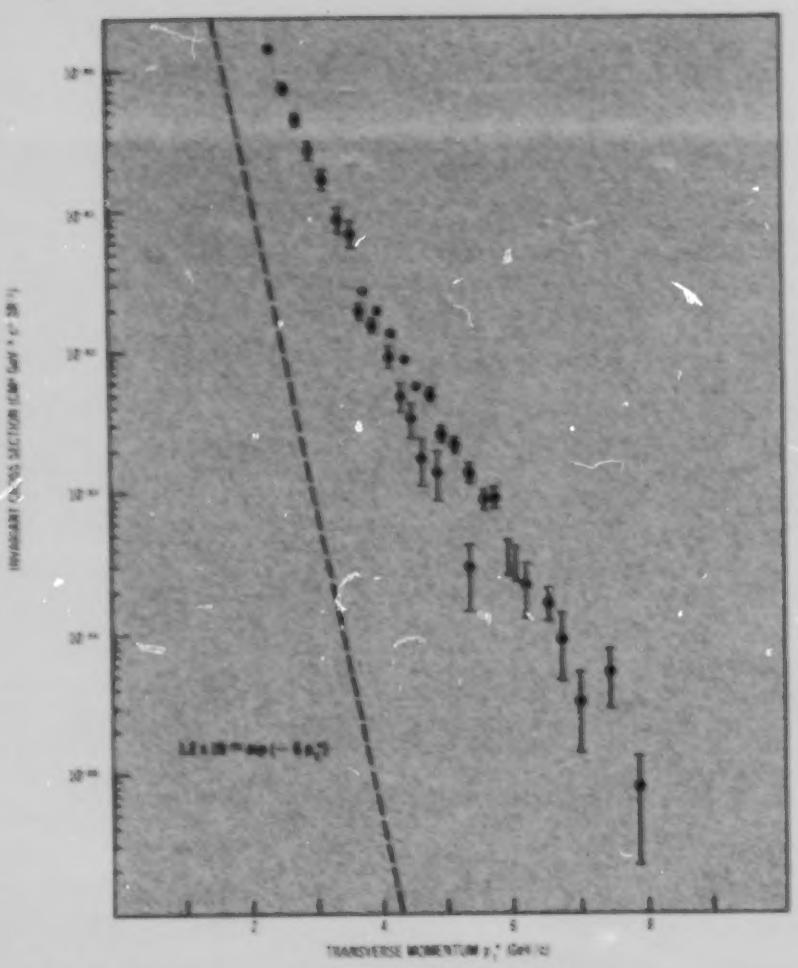
To further substantiate this concept of nucleon structure, higher energy scattering from nucleons must be observed. The need for the higher energy results from the fact that smaller dimensions can be probed, and studies of what is going on deep inside the nucleons can be made.

During the past 2 years, new facilities have become operative which vastly extend the energy range available for experimentation. At one of these, the proton-proton Intersec-

ting Storage Rings (ISR) at the European Center for Nuclear Research (CERN), a collaboration of scientists from Columbia and Rockefeller Universities and CERN has performed an important experiment which has prompted great interest in possible parton-parton interactions that take place when two protons collide.

At the ISR, two 30 GeV proton beams which circulate in opposite directions are allowed to collide in the interaction regions (a GeV is one billion electron volts). The resultant center-of-mass energy of 60 GeV is greatly enhanced over that obtained when a moving proton of the same energy strikes a stationary proton. For comparison purposes, a 400 GeV proton striking a stationary proton at the National Accelerator Laboratory results in a collision of 27 GeV center-of-mass energy.

The purpose of the ISR experiment was to study the momentum distribution at 90° of π^0 mesons produced in collisions of two protons. Two identical lead glass spectrometers were placed at 90° on opposite sides of the colliding proton beams. The spectrometers detected and measured the energy of the photons emitted in the spontaneous decay of the π^0 meson. Earlier data on secondary particle production at lower center-of-mass energies had displayed an exponential decrease with increasing transverse momentum (the momentum of the secondary particle perpendicular to the "beam" direction) up to transverse momenta of 3 GeV/c. The ISR data, going up to a transverse momentum of 8 GeV/c, show an excess over the exponential behavior which starts between 1 and 2 GeV/c and are suggestive of a possible power law behavior.



Results from an experiment in the CERN Intersecting Storage Rings show cross section for π^0 production near 90 degrees as a function of transverse momentum. Earlier experiments at lower energies had suggested exponential behavior comparable to the dashed line. New data show a significant departure. The black points were taken at energies of 26 GeV, the colored ones at 22 GeV.

If it is assumed that neutral pion production is typical of secondary particle production in general, physicists are faced with the challenge of explaining the unexpectedly large amount of secondary particle production at high transverse momentum. They also must explain the increase in secondary particle production cross section for fixed transverse momentum with increasing center-of-mass energy of the colliding proton-proton system. Qualitatively speaking, the data appear to be suggestive of scattering from particles smaller than the nucleon itself in much the same way as the Rutherford α particle scattering experiment from gold foils in 1914 suggested that the atom had a tiny core called the nucleus. Attempts are being made to understand the phenomena by modifying the parton model that successfully explained the deep inelastic electron-proton scattering experiments at the Stanford Linear Accelerator Center (SLAC). The ISR experiments, unlike those at SLAC, explore parton-parton interactions for the first time and find behavior

that strengthens the notion that protons are composed of pointlike constituents.

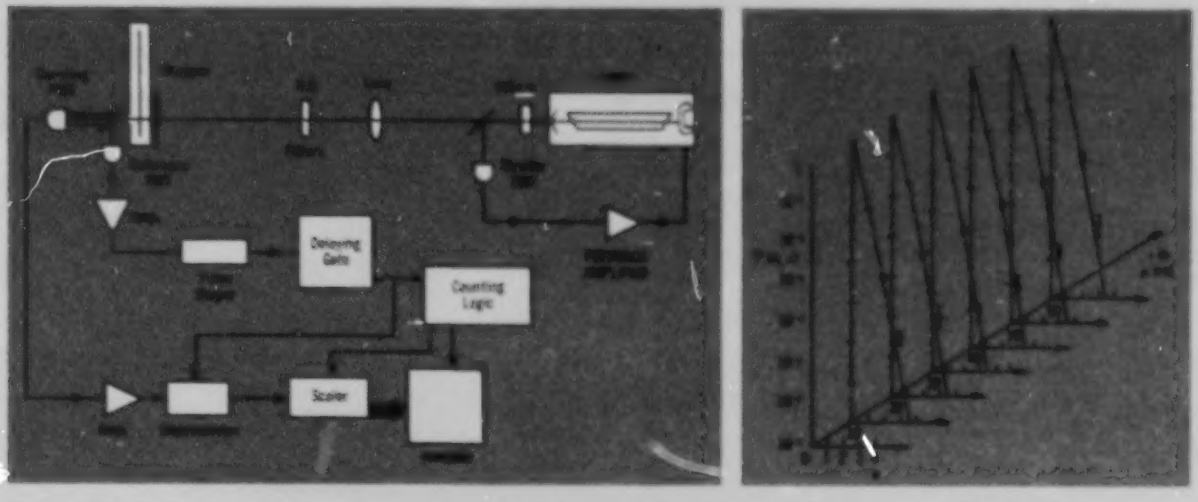
Photons and Photoelectric Emission

Although the theory proposed by Einstein that light energy is carried by discrete quanta or photons rather than by continuous waves is now over 60 years old, questions regarding the physical reality of photons are once again being debated today. The reasons for this debate are largely attributable to E. T. Jaynes and his co-workers at Washington University. They proved by ingenious arguments that most of the effects observed with light that were previously believed to be evidence for the existence of photons could also be explained by a continuous wave—or semiclassical— theory, in which there are no photons. This has given rise to new theoretical speculation, and a number of new experimental tests of the theory of photons—or quantum electrodynamics—have recently been undertaken.

Among these experiments is one by William Davis and Leonard Mandel of the University of Rochester, dealing with the phenomenon of photoelectric emission. It has been known for a long time that when light strikes certain conducting surfaces, electrons may be ejected. According to quantum electrodynamics, an absorbed light photon gives up its energy to the electron and causes its emission. The energy of the electron depends on the frequency, but not on the intensity of the light, although the probability that an electron is emitted at any instant is proportional to the incident light intensity. Because the number of photons arriving per second is proportional to the light intensity, the number of electrons released is also proportional to the light intensity. But it is interesting to note that according to the classical, continuous wave theory also, the probability of electron emission should be proportional to the light intensity. However, an important difference between the two theories is that if energy is carried by continuous waves, there should be a minimum time, the so-called classical energy accumulation time, that must elapse before enough energy has been accumulated to release an electron. On the other hand, if energy is carried by photons, photoelectric emission may occur immediately after the photodetector is exposed to the light.

That this is a crucial point was recognized since early in the century, and a number of experiments have been performed over the past 60 years to test whether photoelectric emission commences immediately after the light beam strikes the detector. However, with one exception, they provided rather little quantitative information. The latest experiment of Drs. Davis and Mandel tested more details than any previous ones in that the entire probability distribution for photoelectric emission was measured at various times immediately after the light beam was turned on.

In their apparatus, the light beam from a single mode laser (as free from fluctuations as possible) passed through a light chopper that turned the beam on and off in times of order of a few microseconds. The beam was



The experimental set-up (left) used in determining whether photoelectric emission could be consistent with a continuous wave theory—as opposed to a quantum theory—of light. Results (on the right), with the measured probabilities of photoelectric emission plotted against various delays between 10 and 60 microseconds following turning on of the light beam, are in accord with quantum theory.

then split into two parts with the aid of a partly silvered mirror: one part was sent to a reference photodetector that determined the time t=0 when the beam was turned on. The other beam was severely attenuated and then fell on the counting photomultiplier tube, which allowed the number of photoelectrons emitted at various times following the turn-on of the light beam to be counted. The number of counts was recorded each time.

In this experiment the classical energy accumulation time was 20 microseconds; i.e., it took 20 microseconds according to the classical wave theory before the light beam accumulated enough energy at the detector to release an electron. If the classical wave theory were correct, one would expect the probability of photoelectric emission to be very small for delay times below 20 microseconds and to increase thereafter. Moreover, one might also expect to find large fluctuations in the number of emitted electrons when the delay is of the order 20 microseconds, as reflected in the shape of the probability distribution.

The results of the experiment, though, show no significant change in the probability as the delay is increased from below to above the classical energy accumulation time of 20 microseconds. This result is completely in accordance with quantum electrodynamics, but would be difficult to reconcile with the notion of a coherent monochromatic light beam in the form of a continuous wave. The experiment represents yet another vindication of quantum electrodynamics and indicates an area in which the new semiclassical theory breaks down. Whether the semiclassical theory can now be modified to accommodate these new experimental results remains to be seen.

CHEMISTRY

Reactions in Solution

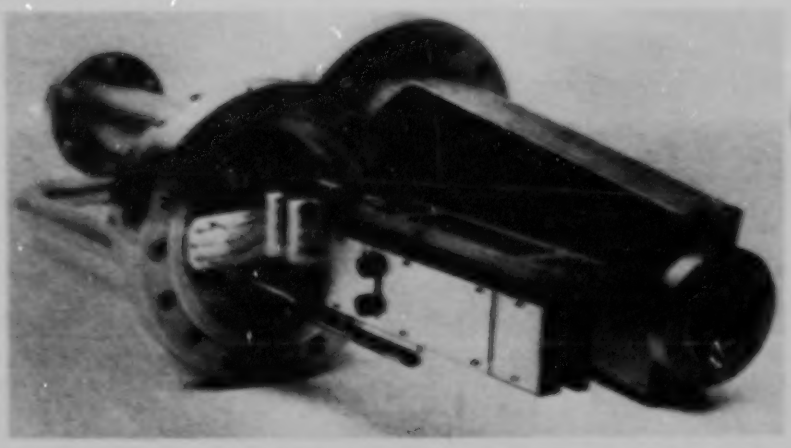
A great many important chemical reactions occur in solutions; examples include biological reactions, many chemical manufacturing processes, and even some air pollution reactions that take place in aerosol droplets. Yet in trying to understand such reactions, most chemists have ignored the solvent, or at best have treated its influence as a minor perturbation on the "intrinsic" chemical properties of the molecules directly involved in the reaction.

Strong evidence is now accumulating that the influence of the solvent has been grossly underestimated. In the extreme, it appears that the entire energy needed to make some reactions take place is involved in getting the solvent out from between the reacting molecules. Certainly there is no question that, in many cases, the effect of the solvent completely overrides the tendencies that the reacting molecules would show if they were unaffected by the presence of solvent molecules.

The evidence comes from a variety of apparently unrelated lines of research. The most dramatic is that performed by John Brauman of Stanford University, using a technique developed by a colleague, John Baldeschwieler, both Foundation grantees. For this work, both men received the American Chemical Society Award in Pure Chemistry, given annually to an outstanding young chemist. The technique, called ion cyclotron resonance (ICR), works on the same principle as the large cyclotrons used in physics. A charged particle (an ion) moves in a magnetic field in a circle, and the frequency with which it goes around the circle depends on its charge, its mass, and the strength of the magnetic field. The charge is nearly always the same, that of a single electron; the magnetic field can be adjusted so that the cycling is in the range of radio frequencies so that radio equipment can be used to detect ions in the cell. Ions of different mass, then, will be detected at different frequencies. If an ion reacts with another molecule introduced into the cell, it will produce a new ion of different mass: this shows up as a new signal to the detector and a decrease in the signal from ions of the mass of the reacting ion. Dr. Baldeschwieler discovered that if a signal was put into the cell at the frequency of the reacting ion, increasing its energy, changes in the number of any ions formed by reactions of the "energized" ion could be detected. This double resonance technique made it possible to sort out complex chains of reaction and, equally important, to tell when ions of a given mass were not involved in reactions leading to new ions.

Dr. Baldeschwieler and Dr. Brauman, who had been studying acidity in solutions, quickly recognized the possibility of using ICR to establish a scale of relative acidities of molecules. A strong acid transfers a charged atom, the hydrogen ion, to a weaker acid. In the ICR cell, then, ions of the stronger acid would act as sources of ions for the weaker one, but the reverse reaction would not occur. This possibility was intriguing since no technique had previously been available to study acid-base reactions in the gas phase with ions of relatively low energy. So they collaborated in carrying out some simple relative acidity measurements in the ICR spectrometer.

The results have astounded chemists. They found, for instance, that methyl alcohol, toluene, and propylene are all stronger acids than water, even though in solution water appears to be a hundred times stronger acid than the alcohols. More shocking, however, are toluene and propylene. These show so little tendency to act as acids in solution that it has only been possible to estimate



This ion cyclotron resonance cell, at the center of a breakthrough in chemical research, is only 2½-centimeters square by 12-centimeters long.

their acidity, it must be at least 20 powers of ten less than water. Dr. Brauman and his co-workers were able to show that these results did not arise because water behaves peculiarly in the gas phase; the only remaining explanation was that the interactions between reacting molecules and solvents were so important that they could completely control the chemistry observed.

Dr. Brauman has not presented his results in quite such dramatic terms, but the point has not been missed. There is now a flurry of activity applying ICR and some gas phase techniques to many reactions that had previously been studied extensively in solution. *Chemical and Engineering News* magazine put it quite succinctly, saying that "... physical-organic chemistry is now being redone in the gas phase." The problem that had prevented such studies in the past was that ions are very hard to form in the gas phase; techniques previously available had made them in high energy states, comparable to temperatures of several thousand degrees. The new techniques allow the gas phase ions to be studied in energy states comparable to those in which they exist in solution, so that the influence of the solvent can now be separated and studied.

Curiously, Dr. Brauman's breakthrough shares two features with other major scientific advances: the general point was anticipated many years earlier, and others had come to similar conclusions more or less independently and simultaneously. Thus, for instance, Michael Polanyi theorized in 1935 that the energy of an important type of reaction should simply be that needed to remove solvent molecules from between the reactants so they could get together. And the year in which the first of Dr. Brauman's ICR papers was published also saw a series of papers by another Foundation grantee which provided both theoretical and experimental bases for saying that dissimilar factors were important in determining acidity in the gas phase and in solution. Calvin Ritchie of the State University of New York, Buffalo, had spent several years doing elegant and painstaking studies of acidities in several solvents other than water. A very careful and detailed analysis of trends led him to the conclusion which had also emerged from Dr. Brauman's work. Dr. Ritchie has continued with studies on the type of reaction cited by Dr. Polanyi and, again by careful analysis of a large body of data gathered with extreme care, has concluded that Dr. Polanyi was quite right. Just recently, Dr. Brauman and a former student of Dr. Baldeschwieler, Robert McIver, have done the ICR studies on the same kind of reaction; their preliminary results seem to confirm Dr. Ritchie's conclusion. This confirmation by two quite different kinds of study makes it much easier to accept the ideas being developed, however much they may differ from the concepts generally accepted.

The implications of this new way of looking at reactions in solution are only beginning to be explored. The ICR studies now being done should help bring order out of many phenomena that have been difficult to understand, as well as turn up some new surprises. The emphasis on the role of the solvent is leading to renewed interest in the structure of liquids and the theory of solutions. And the impact in industrial processes and in understanding biological reactions is still in the future. One idea which has not even been thought out carefully, but must surely be tested, is that the remarkable catalytic properties of enzymes may depend, at least in part, on their ability to selectively remove water molecules from around the parts of molecules that need to be exposed for reaction.

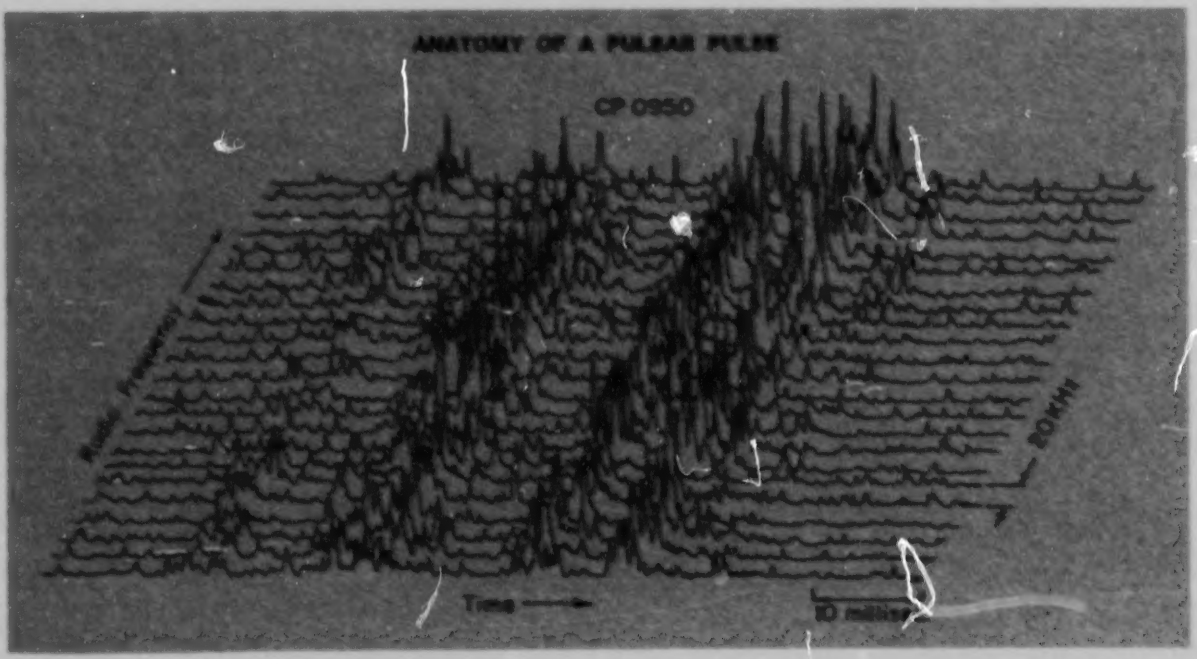
ASTRONOMY

Pulsars

Since their discovery in 1968, pulsars have intrigued and puzzled observational and theoretical astronomers the world over. These objects are the final evolutionary remnants of stars that have burned their nuclear fuel and cast off most of their mass into interstellar space in a supernova explosion. The remainder of the material has collapsed into a super-dense, rapidly spinning neutron star having a mass about the same as our Sun, but a diameter of less than 10 miles. Off-axis alignment of the magnetic field causes radiation from the object to sweep past an observer in time with the rotation, much as a lighthouse beacon sends its signal continuously but appears pulsed to an observer.

The radiating mechanism of the pulsar is of great interest, and it now seems that we are closer to understanding some of its features. During the past year special electronics circuitry was developed at the National Astronomy and Ionosphere Center in Arecibo, P.R., which allows the observation of pulsar signals at as many as 32 frequencies at the same time, and with time resolution better than 100 microseconds. This equipment, combined with the very high signal-to-noise ratio achieved at Arecibo, has allowed very high resolution in both time and frequency of single bursts of pulsar radiation. Such data have been very successfully recorded, and through a suitable mathematical transformation lead to an accurate description of the geometrical arrangement of particles in the radiating region of pulsars. It is found that the particles, which have energies of the order of 10 million GeV, are arranged in compact bunches of very high density. These bunches are about a tenth of a meter in size and they are separated one from another by distances of a few meters. Ensembles of several hundred such bunches occur in well-defined units, with each ensemble being a few tenths of a kilometer in diameter. In each bunch of particles, the 10 billion or so particles move in unison, causing the emission of an enormously intense radiation field. In fact, the power density is such that each square inch of one of these ensembles radiates on the average some million megawatts in power, an amount equal to the total production capacity of all the electrical generating plants on Earth.

Several mechanisms have been proposed to explain the very high energy of the particles. However, the physics by which the particles are led to be segregated into discrete, very



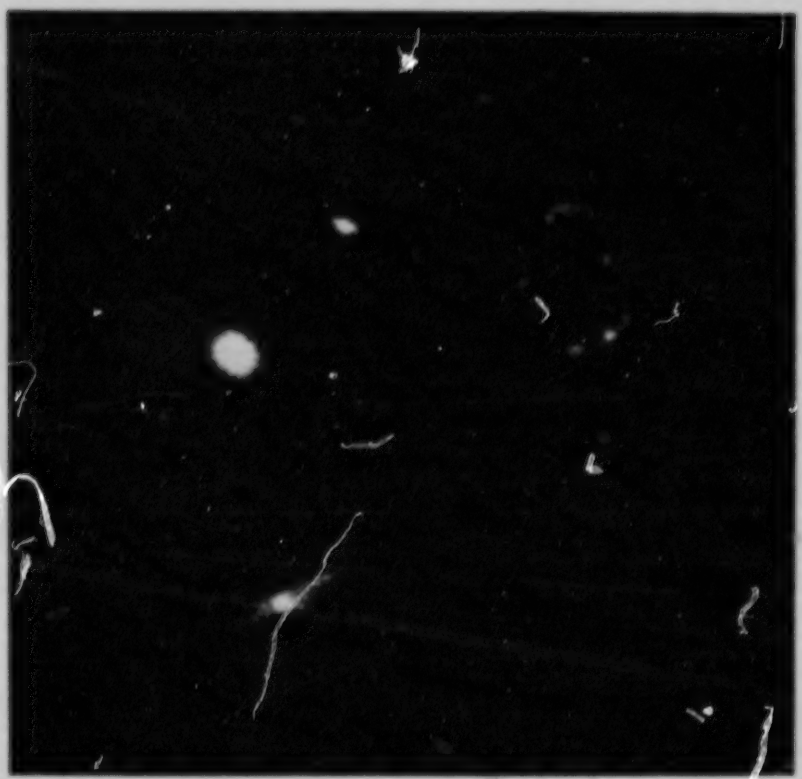
In this single pulsar pulse (recorded at 23 different radio frequencies at the National Astronomy and Ionospherv Center) at least 400 individual peaks in the emission can be seen. Data like these are leading to accurate descriptions of the radiating regions of pulsars.

dense bunches has not been solved. Existence of this phenomenon and its explanation are of great interest, however, since similar phenomena can be expected in such important situations as thermonuclear fusion power generators.

Ring Galaxies

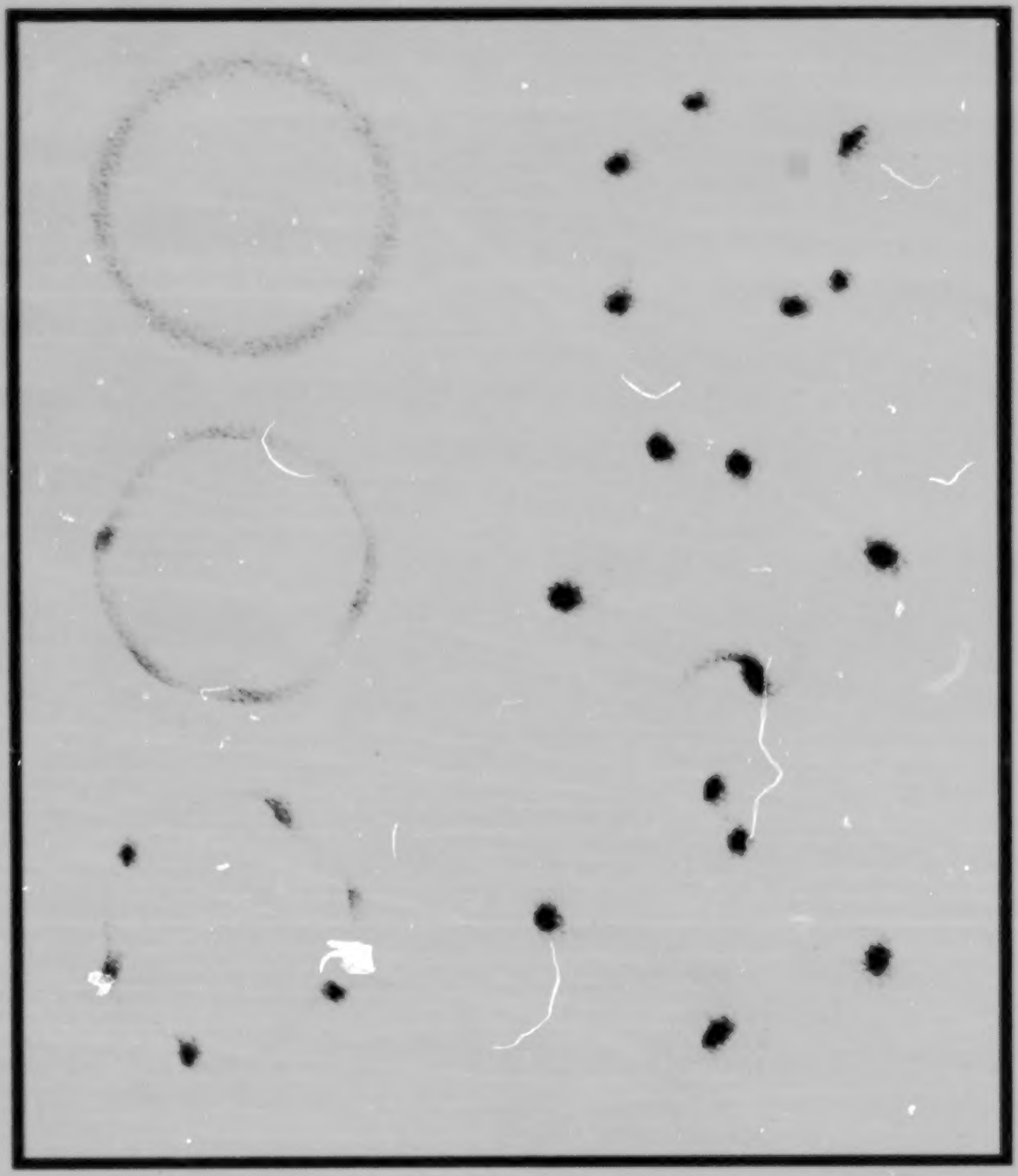
One of the great astronomy success stories of the past 40 years is the gradual unfolding of our present understanding of the life cycle of individual stars. From their beginnings in the dusty clouds in interstellar space to their final demise as white dwarfs, neutron stars, or possibly, black holes, a coherent and self-consistent picture now exists. The same cannot be said for the conglomerates of 10 billion or more stars which we call galaxies. However, first attempts at understanding the dynamic evolution of these objects are now possible, using both observation and computer simulation. An intersting new class of galaxies is now the subject of research by John Theys and his colleagues at the Kitt Peak National Observatory. These are the so-called "ring" galaxies which are presently believed to represent an early stage in galaxy formation.

Photographically, a ring galaxy appears as a luminous elliptical ring with either an off-center nucleus or no nucleus at all. It has been found that each ring galaxy has at least one companion galaxy near the minor axis of the ring. These companion galaxies are believed to be the trigger mechanisms that produce the young ring galaxy. Evidence exists that the companions were, at the time of ring formation, quite close to the embryonic rings and are now moving away. A good estimate of the age of the ring can therefore be made by dividing the distance between the ring and its companion by the present velocity of the companion relative to the ring. This technique sets upper limits for the ages of these ring galaxies of the order of 100 million years—making these objects mere infants on a time scale in which the Earth is more than 40 times older. Helping to confirm this young age for the rings is the fact that the light from the stars in the rings apparently comes only from the youngest types of stars, also having ages no more than 100 million years.



The ring galaxy VII Zw 466 is shown with three companion galaxies. The upper companion is thought to be instrumental in the formation of the ring. The ring itself has a diameter of 80,000 light years and an estimated mass equivalent to 10^{11} solar masses. This photograph was taken with the new 4-meter Mayall telescope at Kitt Peak National Observatory.

Dr. Theys has proposed that a ring galaxy originates through the collapse of an intergalactic cloud of gas, possibly containing dust as well. The collapse is caused by an instability triggered in the cloud by the presence of the companion galaxy; however, the detailed physical processes by which this happens are not yet understood. Such intergalactic rings of gas and young stars are also unstable and will further break up into a ring of density concentrations or "beads." In fact, all of the observed ring galaxies show distinct evidence of the development of such condensations. Dr. Theys and his colleagues are studying computer-simulated models of the evolution of young ring galaxies, and from this work they predict that the rings will rather quickly (in another several hundred million years) fragment into a cluster of individual galaxies of masses of about 10 billion stars each. Hence, a ring galaxy is not believed to be a long-lived phenomenon, and the fact that even a few of these unusual objects have been identified suggests that the formation of rings is a fairly commonplace occurrence in the universe. More commonly observed are chains or clusters of a few galaxies, and these may indeed represent



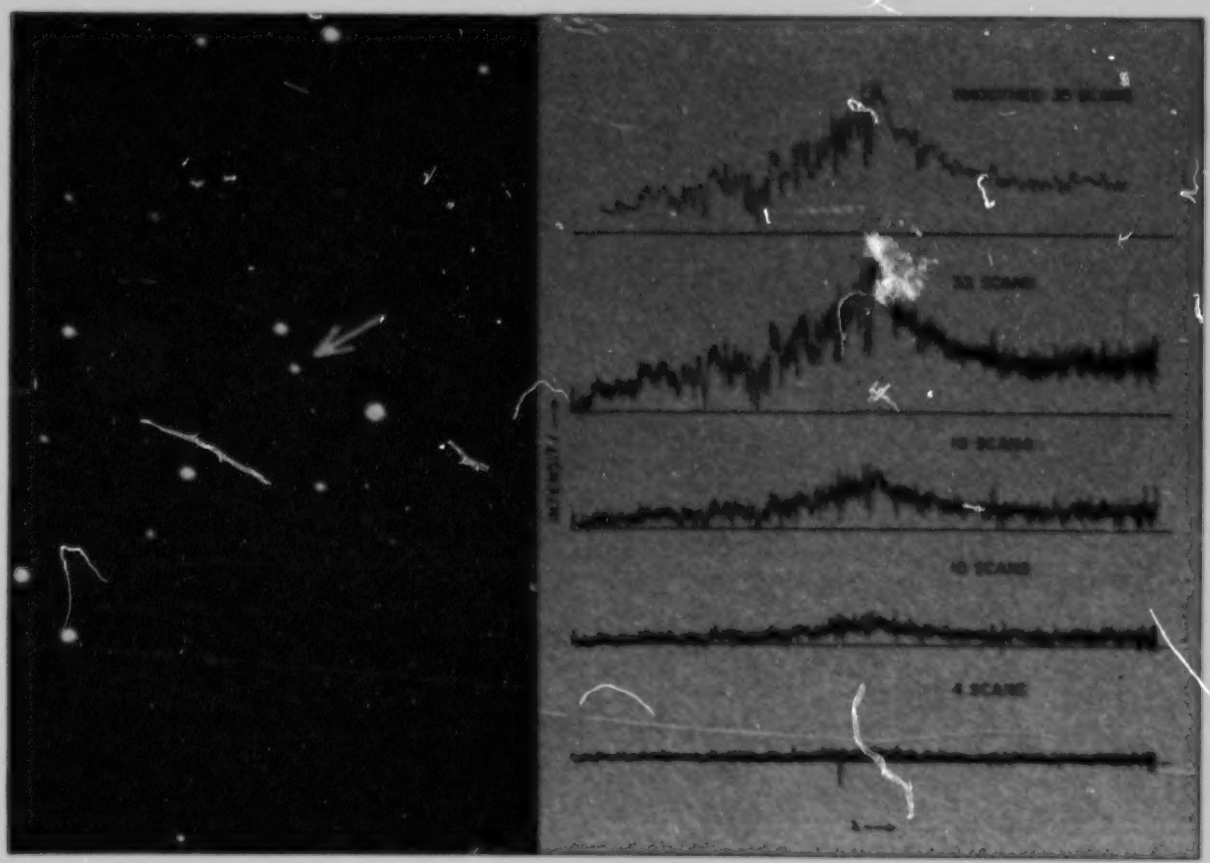
This computer simulation of the evolution of a self-gravitating, rotating ring of gas shows the development of the density condensations and the subsequent final fragmentation of the ring into separate galaxies. When scaled to the ring galaxy VII Zw 466, the total time represented in this sequence is about 200 million years.

the next longer lived stage in the evolution of these fascinating objects.

Quasars at High Redshifts

This year saw the identification of two quasars with redshift values in excess of three. [A redshift refers to displacement of light toward longer wavelengths, which may be caused by the high speed with which the object emitting the light is moving away from the observer.] They are thus the most distant objects known, if the redshift is attributed to the general expansion in a "big-bang" universe. In January 1973, astronomers at the University of Arizona used their 90-inch telescope to measure a redshift of 3.40 for the source OH471. (The "O" stands for Ohio State, where the survey in which the source was first detected was done; H471 gives its approximate position.) The redshift, if it is due to the Doppler effect, implies a velocity of recession nearly 90 percent of the velocity of light. Even more recently, on May 11, 1973, astronomers at the University of California's Lick Observatory measured a quasar redshift of 3.53.

The measurements at both observatories were made possible by the development of electronic aids. At Lick Observatory, a new spectrum scanner enables astronomers to obtain and store data from a particular object more quickly and with greater precision. Data for both the object of interest and the sky background are accumulated directly on a silicon target, rather than in a photographic emulsion. At the end of the exposure the target is scanned with an electron beam, and the intensities are immediately converted to digital form. The sky background is automatically subtracted, and the data are stored on magnetic tape. Data from many scans can be combined, a very difficult job with photographic plates because of their nonlinear response function. Because the silicon



A new electronic spectrum scanner recently installed on Lick Observatory's 120-inch telescope permits the combination of individual scans to attain greater precision than is possible with photographic techniques. This is shown in the built-up spectrum of quasar OQ172—indicated by the arrow in the photograph—the most distant object known in the universe.

target system is much more sensitive than previous systems, a light-amplifying guider system is used to enable the astronomer to find and record an object that cannot be seen directly.

Some advantages of the Lick Observatory scanner are that observation time is a factor of 10 to 50 less than with conventional photography, the strong night sky contribution can be accurately subtracted, the numerical output can be accurately calibrated because the system is essentially linear, and the ability to see the data "on line" increases the observing efficiency.

One important feature associated with the spectra of these newly discovered quasars is the rich array of absorption lines. In many quasars absorption lines have been measured with redshifts less than that of the emission spectrum. This is interpreted as either material shot out of the quasar towards the observer at very high velocity, or else absorption of the quasar light by material along the line of sight. If the latter indeed turns out to be true, then the history of the universe is written in the spectrum of these quasars—a history going back to a time when the universe was only one-tenth its present age.

MATHEMATICS

Initial Value Problems

The solution of the initial value problem for certain classes of nonlinear partial differential equations is of considerable importance in many scientific disciplines. The initial value problem is: Given a set of initial data, describe the behavior of the system from that point on. A characteristic of these problems is that they are dispersive: The velocity of propagation of a small disturbance depends upon wavelength. Nonlinear and dispersive properties compete while dissipation is negligible.

One of the important equations of this type is the Korteweg-deVries (KdV), which was first suggested in 1895 to describe the development and propagation of moderately small amplitude shallow water waves. Here, the effects of non-linear breaking of the waves are balanced by dispersion. Subsequently it was discovered that this equation described many other phenomena, such as the propagation of long surface and internal gravity waves in the ocean and the atmosphere, magnetohydrodynamic waves and ion-acoustic waves in a cold plasma, and rotating flow in a tube. Another initial value solution, the Sine-Gordon equation (1939), describes the propagation of dislocation in a one-dimensional crystal and may be relevant for liquid crystals. It also represents the current balance in a Josephson junction. The special solutions of this equation, called traveling "kinks," may provide the model for the transport across the lipid membrane of a biological cell. Other equations in this class have a wide range of direct physical applications.

The first significant breakthrough came in a truly remarkable 1967 paper by C. Gardner, J. Green, M. Kruskal, and R. Miura, which outlined a method by which the general solution of the KdV equation could be obtained for appropriate initial data. The next important step was the work of V. Zakharov and A. Shabat, who, in 1972, showed that another equation in this class could be solved using ideas similar to that of Dr. Gardner, et al. The most recent work (supported by NSF), by A. Newell, M. Ablowitz, D. Kaup, and H. Segur, was stimulated by an NSF-sponsored Conference on Non-Linear Wave Motion in July of 1972 at Clarkson College of Technology. In a series of papers, they solve the Sine-Gordon equation and generate a technique for the solution of a wide class of dispersive equations and for extension of this technique to problems with higher derivatives, as well as subsuming many linear problems.

There are four principal steps in the solution: (1) Set up an appropriate linear scattering problem in the "space" variable where the unknown quantity of the original dispersive equation plays the role of the potential (the driving force in the scattering problem); (2) Choose (guess) the "time" dependence of the characteristic functions of the scattering problem in such a way that the characteristic value remains invariant as the potential evolves according to the dispersive equation; (3) Solve the direct scattering problem at the initial "time", that is, on the surface where the initial data are prescribed; and (4) Solve the inverse scattering problem at later "times." If the characteristic values corresponding to the bound states and the "time" dependence of the other scattering data are known, the potential can be reconstructed. The potential is the solution to the original dispersive equation for all time. The characteristic values of the scattering problem play a prominent role in the solution. They may correspond to solitary permanent waves which maintain their permanent shape, even interacting with each other without distortion.

As in much of mathematics, answering questions poses many more questions. How can one determine when a problem can be solved by this procedure? What is the physical significance of certain solution states? Can the theory be extended to higher dimensions, or modified for cases in which there is weak dissipation? There is considerable interest in these and other questions by workers in many other disciplines, and investigation of these questions is underway.

BIOLOGICAL AND MEDICAL SCIENCES

NSF-supported research in the biological and medical sciences—which showed a modest increase in 1973—focuses primarily on understanding the biological community of which man is a part. This is approached through studies of biological structures, functions, relationships, interactions, and their changes in time at many levels—molecular through ecosystem. And while individual research projects do not as a rule concentrate on specific problems in areas such as health or agriculture, as examples on these pages show, the basic biological knowledge derived from these studies often contributes to important applications.

The Human Cell Biology Program, established in fiscal year 1972, initiated a number of promising research projects in 1973. It has also supported—in conjunction with development of a Cancer Research Center specifically directed to the needs of the National Cancer Institute—a cell production facility, at the Massachusetts Institute of Technology. The cell production facility, which is not intended to serve the cancer research program, can take advantage of access to instrumentation and of the simultaneous development of facilities. The NSF-supported production facility will provide cells and cellular components in quantity to investigators at MIT and the Boston area for research directed toward achieving an understanding of how the human cell functions and reproduces itself.

While it has been possible to provide only modest expansion for curatorial support for research collections in museums and herbaria, a program initiated in fiscal year 1972, these grants have already permitted a substantial improvement in the operation of the recipient institutions. Perhaps even more important, the activities of the Foundation staff in connection with them, together with encouragement from the Smithsonian Institution, have stimulated the institutions and individuals responsible for these research collections, as well as the scientific communities that use them, to give more serious attention to establishing priorities from a national perspective. A new organization, the Association of Systematic Collections, has been formed; it promises to be an effective vehicle for the required cooperation and the development of a comprehensive approach to more effective utilization of the collections.

A major budget increase this year has been for research on biological regulation of pest populations. This was primarily to permit NSF and the Environmental Protection Agency (EPA) to take over full support for academic scientists participating in the project on "Principles, Strategies, and Tactics of Pest Population Regulation in Major Crop Ecosystems" headed by Carl Huffaker at the University of California, Berkeley, (described briefly in the *National Science Foundation 1972 Annual Report*). The Department of Agriculture will continue to contribute to this research through participation by Agricultural Research Service and Cooperative State Research Service personnel and through joint oversight with EPA and NSF.

Regulation of Pest Populations

Though the project referred to above is still in an early stage of its development, results from another project that has been supported by NSF for several years illustrate some of the questions that must be examined in making maximum use of biological control methods. In this research at the University of North Carolina, Robert Rabb is investigating the populations of *Heliothis zea*, the corn earworm, and *Heliothis virescens*, the tobacco budworm. Together they represent perhaps the most important agricultural pest complex in North and South America. The corn earworm, discussed here, attacks tobacco, cotton, corn, soybean, peanut, tomato, and a variety of less important plants.

Current inability to regulate these pests is not for want of attention to the problem. Many millions of dollars have been spent on control measures, heavily weighted toward attempts at chemical control or eradication. Since the caterpillars of this moth feed inside the buds of fruiting bodies of the plants, they receive a high degree of protection from pesticides. In addition, the chemical approach has suffered from the usual problems of deleterious effects on non-target organisms and increasing resistance of the *Heliothis*.

Traditionally, research on control methods has taken a crop-by-crop and pest-by-pest approach. This is known to be ecologically unsound, and newer approaches, including those developed by Dr. Rabb and his associates are attempting to expand the scientific basis for regional, multicrop management strategies. Their initial approach is to examine a single pest or pest complex on all the crops of a region.

An index of corn earworm populations is provided by the production of corn earworm pupae. It is evident that by far the largest population is present on corn, but this population has not been subject to control for two reasons. First, the damage to field corn is not economically serious, and by the time the corn is harvested the earworms have left the ears to decend into the ground to enter the pupal stage. Second, it was believed that corn did not contribute significantly to the number of overwintering pupae—the source of the population in the next growing season. Pupae formed early in the

season continue development to emerge as moths later in the summer. Only those pupae formed later in the summer enter diapause, a state of arrested development, and maintain the pupal state until the following spring and summer. It has been assumed that the earworm population on corn in September was too small to produce many overwintering pupae, but Dr. Rabb finds that is not the case. Corn makes the largest contribution to the population of overwintering pupae.

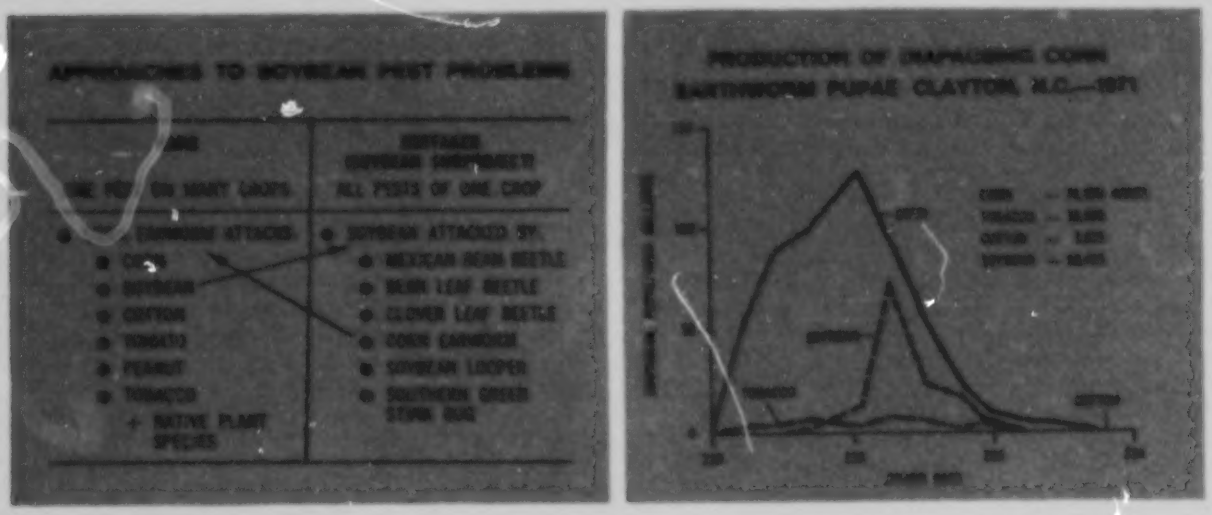
These results strongly suggest that any management schemes will have to involve control of this pest on corn, as well as on those crops where damage is of economic importance, such as soybeans, tobacco, and cotton. Further examination of the problem will involve a study of the range and pattern of dispersal of the adult moths as they emerge from pupae.

In the course of these studies it has also been found that the spatial distribution of soybean plants is a determining factor in the severity of damage produced by *Heliothis*. If the spacing between rows, or the timing of planting, is such that there is a continuous canopy at the time of flowering (no open space between plants within or between rows), damage is not severe. This is because the caterpillar of another moth species which feeds on the soybean plant earlier in the season is commonly infected with a pathogenic fungus. The continuous canopy apparently maintains a high humidity which supports the persistence of this fungus, which then attacks the *Heliothis* as they hatch—before they can destroy the blossoms. The idea that cultivation practices may be used to control pest infestations is hardly new, but has been largely ignored in the United States in recent years. It is important in implementing such an approach, however, to understand the basis for it. The closed canopy approach in the present instance would not work in the absence of the pathogenic fungus and its earlier host.

The real magnitude of pest management problems may be illustrated by contrasting the Rabb approach and the Huffaker approach, which is crop-oriented. For each pest one needs to consider all the reservoirs in crops and other plant communities, while for each crop one needs to consider all the pests which may be important. It is for this reason that we are pleased that the Rabb and Huffaker projects are coupled on soybeans in North Carolina, and that attempts to develop computer models of the systems are being strongly encouraged.

Viruses in Cancer Cells

Bernard Roizman of the University of Chicago recently reported finding that a fragment of the genetic material, DNA, of a herpes virus was present in, and an integral and functioning part of the DNA from a sample of human cervical cancer. This is perhaps the most direct evidence to date for the involvement of a virus with a human cancer, and is of further interest in implicating a DNA-containing virus, since most attention previously had been directed toward presumed tumor viruses of the RNA type. Although Dr. Roizman's observations do not prove that the virus has caused the cancer, they do provide the basis for



Research on the role of corn as a source of overwintering corn earworms (right)—relatively harmless to field corn but which cause severe damage to nearby crops of tobacco, cotton, and soybeans—has shown it to be much higher than previously assumed. Such findings emphasize the obvious advantages in cooperation between studies of single pests and of single crops (left).

the following testable hypothesis: At some much earlier time the individual who developed cancer was infected by the herpes virus, which may or may not have been obvious then. In perhaps only one or a few cells of the cervix the virus was carried in a latent form and eventually a segment of the virus DNA was inserted into the DNA of the cervical cells. This resulted in the expression of new characters which are in some way responsible for the cell becoming malignant.

Some 15 years ago, NSF initiated support of Dr. Roizman's research as a basic investigation in molecular biology on the nature of the molecules that make up the herpes virus. He was, of course, aware that herpes viruses are responsible for such things as cold sores, shingles, and chicken pox, but it seemed clear to him as it did to many other biologists that virus diseases could only be dealt with effectively on the basis of an intimate knowledge of the virus. The mechanisms of infection, multiplication of virus, and effects on infected cells could only be understood and dealt with adequately when the molecules and their properties and functions were understood. In the course of subsequent years he has studied herpes simplex viruses that infect man and those associated with renal tumors in frogs and lymphatic tumors in chickens. The isolation and characterization of the DNA from a variety of sources made it possible to refine an essentially chemical method for detecting and identifying the virus DNA in the human cancer tissue.

Dr. Roizman found that a fragment amounting to about 39 percent of the DNA of herpes simplex 2 virus was incorporated into the genome of the human cervical tumor cells, with an average of 1 virus fragment per cell. Applying the hybridization technique to the RNA of the cervical cells, he could also show that some of this had been transcribed on viral DNA, but that these transcripts corresponded to only about 5 percent of the viral genome. In other words, some part of the genetic message of the virus is being expressed in the tumor cell, and might be related to the fact that it has become malignant.

Photosynthesis

It has long been known that plants and some bacteria contain solar energy cells, capable of using light energy to drive the chemical reactions essential for life and growth. These solar energy cells always contain the green pigment, chlorophyll, and one of the great achievements of the first quarter of this century was the isolation of chlorophyll and the determination of its structure by the German biochemists Richard M. Willstatter and Hans Fischer.

This fascinating phenomenon has been the object of a great deal of attention since then. As early as the 1930's Ralph Emerson and William Arnold concluded that molecules of chlorophyll in plants must act cooperatively rather than individually in this energy conversion, and C. B. Van Niel suggested that the first step must amount to a separation of oxidizing and reducing activities. Later, in one of the early demonstrations of the power of radioactive isotopes, Melvin Calvin was able to clarify the early steps by which the carbon fixed in photosynthesis is incorporated into sugar. It was also possible to show that the reduction of CO_2 is not immediately linked to the initial reactions involving light.

Subsequent work of many people, including NSF grantees Daniel Arnon and R. B. Park of the University of California, Berkeley, David Krogmann and R. A. Dilley of Purdue, and Bessel Kok of the Research Institute for Advanced Studies, to name a few, have clarified major aspects of the associated reactions. In plants, two photosystems with rather different properties occur together. Photosystem I does not generate O_2 and does not fix CO_2. The energy absorbed by chlorophyll is used to generate high-energy phosphate bonds in ATP which may be subsequently used for various energy needs of the cell. Photosystem II is more complex, and is non-cyclic. It generates a coenzyme, reduced NADP, which can be used to reduce CO_2 to form carbohydrates. At the same time, it uses water in producing reduced NADP, and thus evolves oxygen. Bacterial systems of two kinds are known, one of which appears to be similar to plant photosystem I, and the other somewhat like photosystem II in generating NADPH and leading to CO_2 fixation, but not able to use water as the substrate and hence not evolving oxygen in the process.

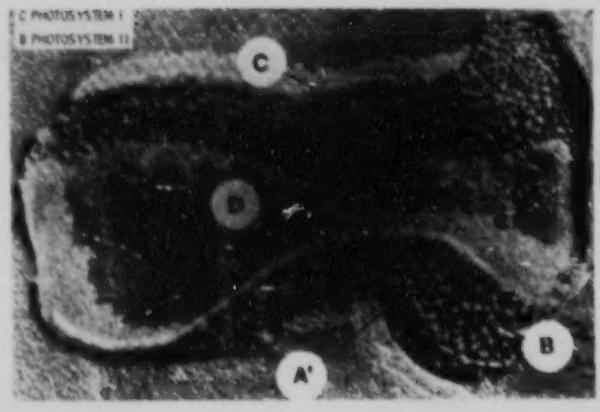
At the same time, knowledge of the physical organization of plant photosystems has progressed substantially. Photosynthesis is carried out in special organelles called chloroplasts, and these have been shown to contain a folded and tightly packed system of membranes, the grana. More recent electron micrographic studies have shown that there are characteristic small particles associated with the membranes, and these are believed to be packages of the essential components of photosystems I and II. However, the isolation of these ultimate units of the photosynthetic apparatus from plants has met with limited success.

Since chlorophyll at physiological temperatures behaves pretty much like any other pigment when it absorbs light, much of what must happen in the plant during the initial reaction following absorption of a photon has been inferred. Recently, however, George Feher at the University of California, San Diego, has monitored chlorophyll attached to cellular molecules. He adapted methods developed initially by Roderick Clayton of Cornell for isolating from bacteria what appears to be a minimal photosynthetic unit. This consists of three small proteins, molecular weight about 22,000, 20,000, and 28,000, four molecules of chlorophyll, and two molecules of the pigment phycobilin. Illumination of these isolated reaction centers produces a change in the chlorophyll absorption spectrum and the appear-

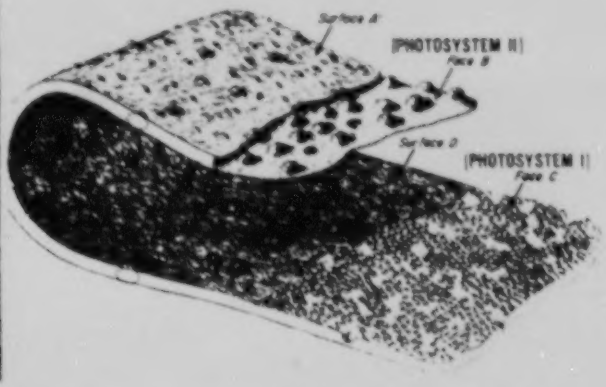
ance of a new electron spin resonance signal which confirms the separation of an electron leading to the formation of oxidized chlorophyll. Analysis of the signal by electron nuclear double resonance indicates that the charge of the oxidized chlorophyll is distributed over two chlorophyll molecules, indicating that each reaction center requires two cooperating chlorophylls to carry out the initial photochemical event, and confirming suggestions arising from earlier less direct experiments.

What has been accomplished to date by the cumulative effort of many scientists has made it possible to understand something of the way alternate pathways for incorporating the initial products of photosynthesis have been selected over millions of years under different ecological conditions. While it seems unlikely that we will be able to improve on these results of evolution, this experiment of nature may guide us in devising more efficient energy collectors.

SUBSTRUCTURE OF GRANA AS SHOWN BY FREEZE STRUCTURE



GRANA MODEL



In chloroplasts, sites of a plant's photosynthetic activity, there are thought to be two photosystems. These are shown here on the grana (left), an array of membranes to which are bound aggregates of light-harvesting pigments and proteins. A drawing of a model of the grana (right) shows the location of the two photosystems on the outer and inner faces.

ENVIRONMENTAL SCIENCES

The environmental sciences—earth sciences, atmospheric sciences, and oceanography—dealing as they do with the physical matter, energy sources, and transformations in the Sun-Earth system, are of fundamental importance to all life on the Earth. Research in these areas is aimed at the acquisition of a wide range of knowledge about man's own immediate portion of the universe. This knowledge is becoming increasingly important for his well-being.

Recent major advances in environmental sciences research are largely based on two factors. One is the development and use of sophisticated instruments and techniques for observing and measuring. The other is the exploration of several major concepts as guides for focusing research on the processes that operate in and on the solid Earth, in the atmosphere and the oceans, and in interplanetary space and the outer zones of the Sun.

One major new concept, plate tectonics, approaches the status of a scientific revolution. It serves as a unifying principle for a large portion of research in the earth sciences, as well as for certain aspects of oceanography and atmospheric sciences. Two other phenomena that are important in guiding research in the environmental sciences are the interactions of the solar wind with terrestrial magnetic and electrical fields, and the transformations of energy originating from within the Earth and from the Sun. A few examples of current research supported by programs of the division illustrate the use of these concepts as unifying principles.

The concept that the magnetic and electric field structure surrounding

the Earth is able to confine plasmas and accelerate particles to high energies, and that this field structure may be one of the simpler of the natural systems within the universe to have these capabilities, has emerged during the past 15 years. Recent advances in observing techniques, producing important new information on this magnetosphere, have led to many new hypotheses. These should be tested with synoptic data from many parts of the globe. The importance of the hypotheses to the understanding of many solar and terrestrial processes, and the availability of powerful new ground- and satellite-based observing techniques, form the basis for the planning of an International Magnetospheric Study (IMS) for fiscal years 1976-78. A major commitment of resources available for atmospheric sciences research will be made to IMS.

The idea that the outer shell of the solid Earth is made up of a few plates that move relative to each other has unified much of the subject matter of the earth sciences and explained many of the spatial and time relationships among structural features, seismic zones, volcanic belts, and areas of ore deposits. The importance of this plate tectonics model as a focal point for the solution of some of the unanswered questions concerning the mechanism and sources of energy for both horizontal and vertical movements of the Earth's surface has led to the formation of the International Geodynamics Project, with current participation by nearly 50 countries.

Recent intensive interest in the causes and effects of seismic activity has resulted in the promising possibility that major earthquakes can be predicted and even that preventive measures may be ultimately possible. An agreement for cooperative research on earthquake prediction, earthquake hazard assessment and reduction, and tsunami warnings is a part of the recent U.S.-U.S.S.R. accord on environmental studies. This work is also being intensified in the United States-Japan science program.

Although the flow of energy from the Sun is primarily responsible for sustaining life, driving the weather, and providing directly or indirectly for most of man's immediate energy needs, the heat produced within the solid Earth is also becoming a promising energy resource. The heat flow characteristics in the Earth are important in investigations of igneous activity and mountain building processes and possibly relate to the mechanisms that move crustal plates about. A study funded in recent years by the Geophysics Program on the distribution of radioactive minerals and heat flow in the Rocky Mountains resulted in the discovery of a large heat anomaly in Montana. The possible application of this discovery to geothermal energy is being investigated through the Foundation's Research Applied to National Needs Program, and may result in exploitation by groups including other Government agencies and industry.

The Earth's magnetic field has undergone many fluctuations, including reversals of polarity, by little-known processes that have operated throughout geologic time. Studies of these fluctuations have provided information on the paths of wandering of the polar axis and have also resulted in a time scale, based on reversal chronology, that is directly useful in determining the rates at which volcanic rocks are moving away from the mid-ocean spreading centers in the formation of the present ocean basins. The magnetic reversal chronology is also one of the major tools used in dating cores from the Ocean Sediment Coring Program. These cores are used in interpreting the structural and sedimentational history of the oceans and the chemical and physical processes that have operated in the past.

ATMOSPHERIC SCIENCES

Advances in Atmospheric Prediction

The discovery at the National Center for Atmospheric Research (NCAR) of a method for forecasting violent and damaging winds east of the Rocky Mountains marks an important advance in techniques for predicting small-scale atmospheric features. As had been suspected, the storms are manifestations of powerful mountain wave systems. Whenever strong westerlies are present and a stable air layer overlies the mountains on the western (upwind) side, with less stable layers above and below, heavy winds tend to develop near the surface on the downwind side of the Continental Divide. NCAR meteorologists have developed techniques to make forecasts of useful accuracy if observed upstream conditions can be inserted into a numerical model that predicts locations and amplitudes of surface wind maxima. Collaborating with NCAR, scientists from the National Oceanic and Atmospheric Administration (NOAA) have installed an acoustic sounding system west of the Continental Divide to detect temperature inversions for input to the prediction model. Once perfected, the technique should be applicable to other areas where similar winds occur—in the Los Angeles area, Nevada, trans-Alpine Europe, Argentina, Japan, New Zealand, China, and parts of the U.S.S.R.

A second important advance in atmospheric prediction techniques is

the development of atmospheric prediction models based on isentropic or potential temperature surfaces (surfaces in space having equal entropy) rather than on the more conventional pressure levels. Isentropic surfaces seem to define material atmospheric layers and to closely parallel actual air-mass boundaries. The new technique will give more realistic input for numerical forecasting, and an isentropic model has already been found to outperform conventional models in predicting spontaneous, explosive development of large, mid-latitude cyclonic storms. Isentropic forecasting substantially reduces computer time because it provides detail where it is needed—along frontal zones—and omits detail across large, featureless areas.

Isentropic analysis has also contributed to a study of duststorms and their possible effect on climate. Several years ago, NCAR scientists had concluded that more than half of the total global aerosol content (particulate matter) derives from soils, but the question remained how the dust finds its way into the atmosphere. Aerosols are an important climatic determinant, but conclusive knowledge about whether they cause net cooling or heating of the atmosphere requires measurement of the particle sizes and optical qualities. Large duststorms require a strong source of momentum (such as the upper-level jet stream) and a mechanism for bringing this momentum to the surface over regions of loosely packed soil (such as strong convective mixing to mid-tropospheric heights over the southwest United States). Using a special instrument called a polar nephelometer, NCAR researchers obtained data that showed that atmospheric wind-blown dust contributes to a net atmospheric warming—a reversal of previous assumptions. Further studies of the role of aerosols in the global heat balance will be conducted in the next 2 years as part of the Global Atmospheric Aerosol Radiation Study—a joint program involving three universities, NOAA, and NCAR.

This diagram suggests how variations in upper-level air currents provide the momentum to produce large duststorms.

Flare-Produced Shock Waves

The solar wind is a constant flow of particles moving at supersonic speeds from the Sun into interplanetary space to the Earth and beyond. Satellites have detected it since the early 1960's. When solar flares erupt on the Sun, a mass of particles may shoot out at a velocity much higher than the rest of the solar wind, forming a shock front similar to that created by supersonic aircraft. When the shock front impinges on the Earth's magnetic field 2 or 3 days later, it changes the field's shape, and satellites can detect a sharp increase in the flow speed of the solar wind. Scientists of NCAR's High Altitude Observatory have deduced that the flare ejecta should move as a single unit as they burst outward from the corona and that flare eruptions carry more energy into space than is normally given off by the entire solar corona over several days. During an international seminar on flare-produced shock waves, hosted at NCAR, they presented a possible geometric model to explain how the ejecta stay together as a kind of "cloud" as they travel outward: Magnetic "bubbles" or "bottles" can be formed by the merging of magnetic field lines behind ejected material; the bubble is thermally insulated from the hot solar corona and cools within itself during its expansion into interplanetary space. Optical and radio observations can track its progress, and these measurements closely resemble satellite measurements of the total energy and mass flowing past the satellite. Auroras, changes in the Van Allen radiation belt, and perturbations in the geomagnetic field seem to result from the Earth's interception of the intense waves of

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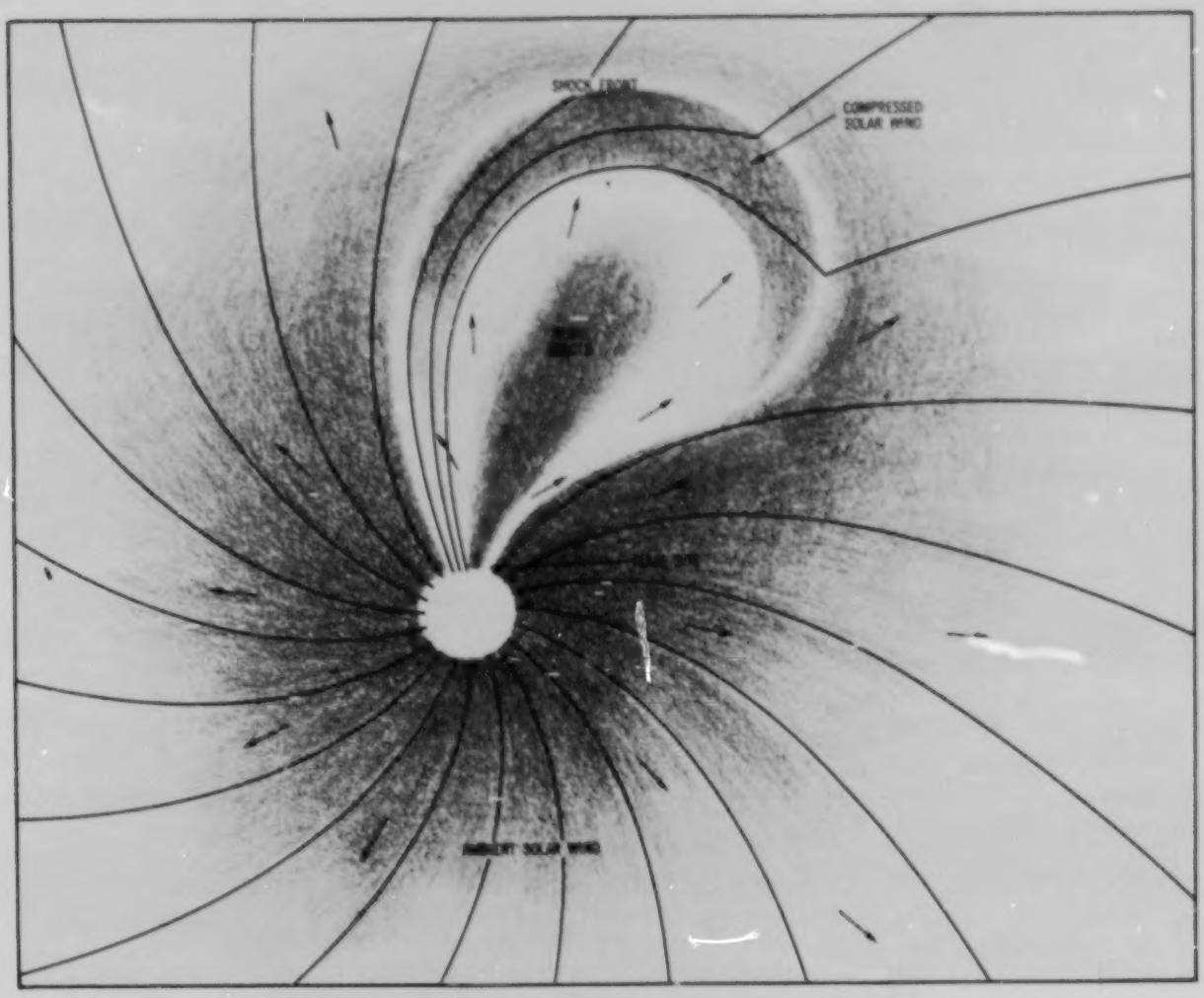


Characteristics of the solar interplanetary medium during a solar flare eruption.

energy. Researchers must still explain how the energy is transferred from the solar wind to the Earth's magnetosphere, and this will be one of the principal objectives of the International Magnetospheric Study to be conducted in fiscal years 1976-78.

Global Weather

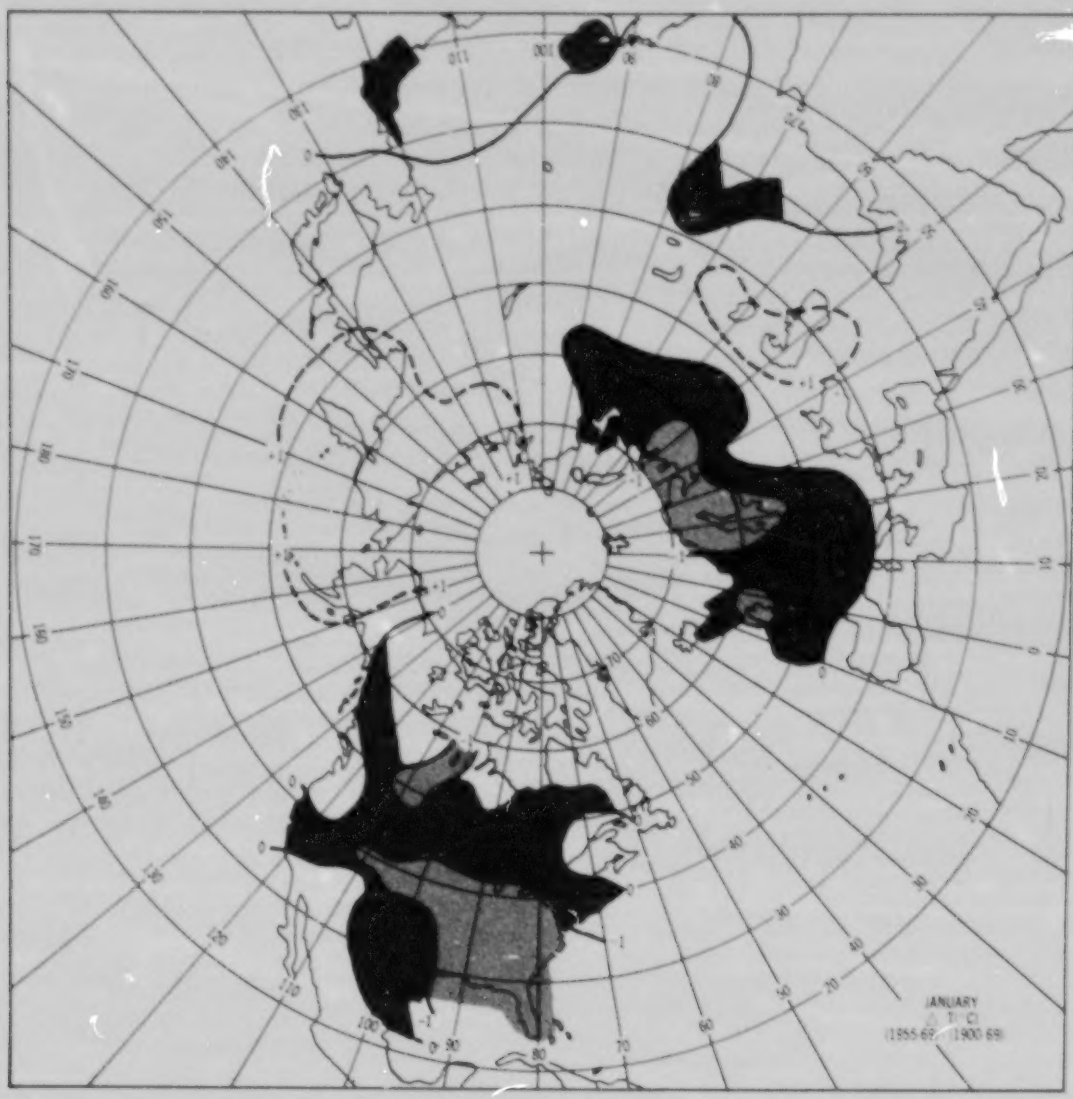
The winters of the latter half of the 1950's and most of the 1960's and early 1970's were characterized by a departure from the usual weather, with warmer temperatures along the west coast of North America, colder temperatures east of the Rockies, colder temperatures in Europe, and warmer temperatures in Siberia. These patterns were associated with intense cyclonic storm activity over the North Pacific and relatively weak storm activity over the North Atlantic. This year-to-year and decade-to-decade variability of weather and climate patterns over the Northern Hemisphere has been a main focus of research at the University of Wisconsin by John Kutzbach and Reid Bryson—work concerned with understanding the world pattern of climate, its causes and mechanisms, its evolution in time, and the impact of climate on the patterns and changes of ecological systems.

Using a variety of statistical techniques, they have identified important "modes" of atmospheric circulation. For example, the intensity and location of wintertime storms over the North Pacific and North Atlantic Oceans undergo significant year-to-year and decade-

to-decade changes which significantly affect downstream weather over North America and Europe respectively. Significant departures of temperature and precipitation from their long-term average values are associated with each of these modes. Characteristically, these departure patterns may cover areas as large as the United States and involve temperature changes of several degrees and precipitation changes of 10 to 20 percent, even when averaged over a decade.

Detailed climatic data for the Northern Hemisphere for the past 70 years show that there have been two intervals of significant circulation changes, the early to mid-1920's and the early to mid-1950's. The climates of the three periods separated by these intervals of change are significantly different.

In collaboration with other units, in particular the tree-ring lab at the University of Arizona, the Wisconsin group is identifying the hemi-



This map shows the January temperature departure pattern (in degrees Celsius) for the years 1955-69 compared to 1900-69. The winters since the mid-1950's have been dominated by a circulation mode that produced increased northerly winds east of the North American Rockies (hence, colder winters) and decreased westerly winds in western Europe (also colder winters). Portions of eastern Siberia and western Alaska experienced warmer conditions.

spheric climatic patterns of the past several hundred years. Preliminary results indicate that the climatic modes observed since the mid-1930's were more common throughout much of the 17th, 18th, and 19th centuries than they were in the first half of the 20th century.

These investigations help to define the bounds of natural climatic variability and represent a reference level against which man's possible impact on climate must be assessed. Also, they begin to make possible the testing of hypotheses regarding causes of climatic variability; for example, the possibility of volcanic eruptions producing global dust veils which affect climate. Finally, as world population increases, agricultural and technological policies become increasingly weather and climate sensitive. For example, most cultivated plants are currently bred to produce optimum yields under long-term average climatic conditions. Since each climatic mode represents a departure from long-term average conditions, crop yields will almost always be below optimum. The global rash of crop failures of the past several years may be an example of this. Planning should begin to take account of information on climatic variability.

EARTH SCIENCES

Ionizing Radiation on Solids

In the past few decades geochemists have taken great strides in their ability to re-create the history of rocks by examining the results of radioactive processes that have occurred in them. Developments in this field continue to provide powerful tools for scientists, and in fiscal year 1973 studies of the effects of ionizing radiation on solids produced several new geochemical discoveries, analytical methods, and practical applications.

Particle tracks are permanent microscopic traces of the passage of charged atomic particles through a crystal. They have been used for a decade to determine the ages of rocks, minerals, and archaeological objects. Particle tracks in meteorites and lunar samples are used to determine the nature and history of cosmic rays in outer space, the exposure histories of rocks on the lunar surface, and the nature of the elements present in the solar system when meteorites were formed 4.6 billion years ago. The techniques for detecting and measuring particle tracks have also produced numerous practical applications, including the production of ultrafine filters for separating and counting bacteria; the location and measurement of radioactive elements in manufactured parts; the development of new instruments for uranium prospecting; and the design of low-level dosimeters for monitoring exposure to radiation.

Robert Walker of Washington University has developed a way of using particle tracks to map the distribution of uranium in meteorites and lunar samples. (Uranium is an important element because it produces radioactive heat and therefore strongly influences the thermal history of the Moon and planets.) In Dr. Walker's method, a slice of the sample is placed next to a sheet of mica, and the two slices are then bombarded with neutrons in a reactor. The neutrons cause the uranium atoms in the sample to split, and the fission fragments leave permanent tracks in the adjacent mica sheet. The more uranium in the specimen, the more tracks are produced. This method not only measures the amount of uranium in a sample, but it also provides a map of uranium concentration. In meteorites, for instance, he finds most of the uranium in small cracks and pockets between the larger crystals of silicate minerals.

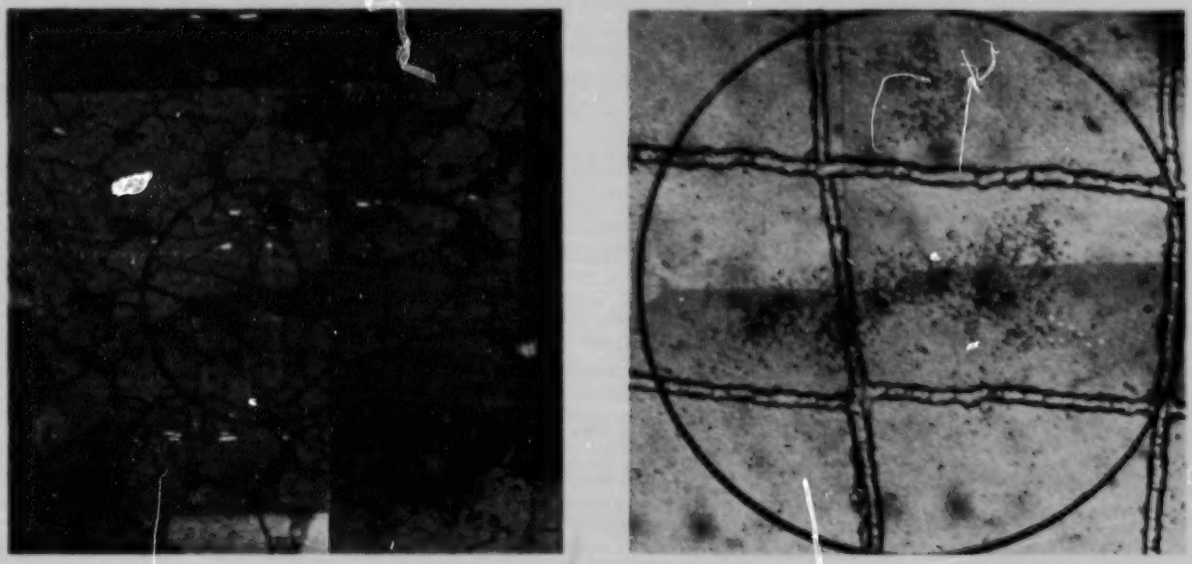
Thermoluminescence is the name for the glow given off from crystals when they are heated after having been exposed to atomic radiation. When the crystals are at normal temperatures, part of the atomic radiation passing through them is trapped and stored; this energy is then released as a glow when the crystals are heated. The intensity of the glow produced when an object is heated depends on the amount of radiation it has received during its lifetime; the more radiation, the more intense the glow. Older objects generally receive more total radiation from natural sources than do younger ones, and therefore, the intensity of the glow can also be used to determine the age of the object.

An impressive application of this method was carried out last year by David Zimmerman, a co-worker of Dr. Walker's, who has developed methods to measure the glow produced by single crystals less than a millimeter across. Dr. Zimmerman's methods made it possible to measure the age of a controversial bronze statue of a horse in the Metropolitan Museum of Art. The statue, once believed to be an ancient Greek sculpture, was more recently regarded as a modern forgery. But the glow given off by a tiny crystal from the ceramic core of the horse indicated an age of 2,000 to 4,000 years, and showed that the statue was unquestionably a priceless ancient Greek sculpture. Dr. Zimmerman's work is another important example of how geochemical studies and methods have become extremely important to scientists in other fields, including art and archaeology.

URANIUM IN METEORITES

POLISHED METEORITE SAMPLE

MICA PLATE



0.1 mm.

URANIUM FISSION TRACKS (BLACK)
10 PARTS PER MILLION

By putting a mica plate next to a meteorite sample, then bombarding both with neutrons, Robert Walker of Washington University can produce particle tracks that reveal the location and amount of uranium in the meteorite. This technique, useful in many applications, shows the uranium (black specks on the mica plate) to occur in cracks between the larger mineral crystals.

OCEANOGRAPHY

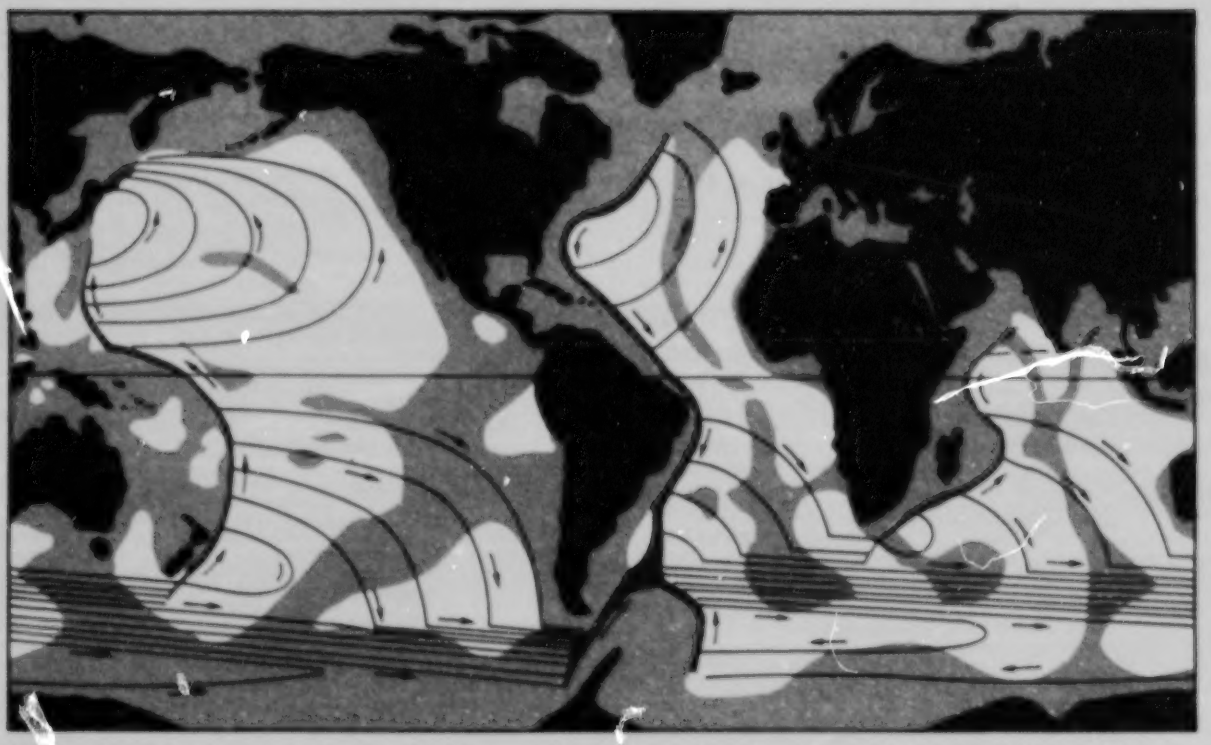
Deep Ocean Currents

In the Atlantic Ocean off the coast of Brazil, a deep-ocean boundary current, similar to the Gulf Stream, flows along the western edge of the deep Atlantic Basin and transports cold bottom water from the Antarctic into the North Atlantic Ocean. Similar deep western boundary currents have been identified in the South Pacific and in the Indian Ocean.

Henry Stommel of the Massachusetts Institute of Technology is leading a research team in studying, together with investigators from the Lamont-Doherty Geological Observatory of Columbia University and three Brazilian scientists, this Atlantic current. To do this kind of research the scientists are using extensive shipboard observations of water temperature and salinity to identify the source of the water and to permit calculation of the current speed using indirect means similar to those used by meteorologists to study winds in the atmosphere. In addition, they measure certain chemical constituents of the water (dissolved oxygen, phosphate, silicate, and nitrate) to determine the probable origin of the water masses involved and to study changes in the waters due to biological and chemical processes since the water sank below the Antarctic Ocean surface.

Such deep-ocean currents have been predicted on theoretical bases by Dr. Stommel and his co-workers. Verifications of their existence and properties have been difficult to obtain since deep-ocean currents cannot be observed directly at the ocean surface. The work of the MIT-Lamont group will provide two highly accurately measured sections from which these deep currents may be studied.

In the future the group plans to test the theory of deep-ocean currents by trying to locate a predicted 4,000-meter-deep high-velocity current at the Equator off Brazil. The theory predicts current speeds as high as 200 cm/sec. To find it they will use Swallow floats, a type of neutral density float that moves with the



Oceanographer Henry Stommel and his co-workers are conducting experiments in the Atlantic Ocean, off the coast of Brazil, to try to verify Stommel's theoretical model—illustrated here—of the world's deep-ocean currents.

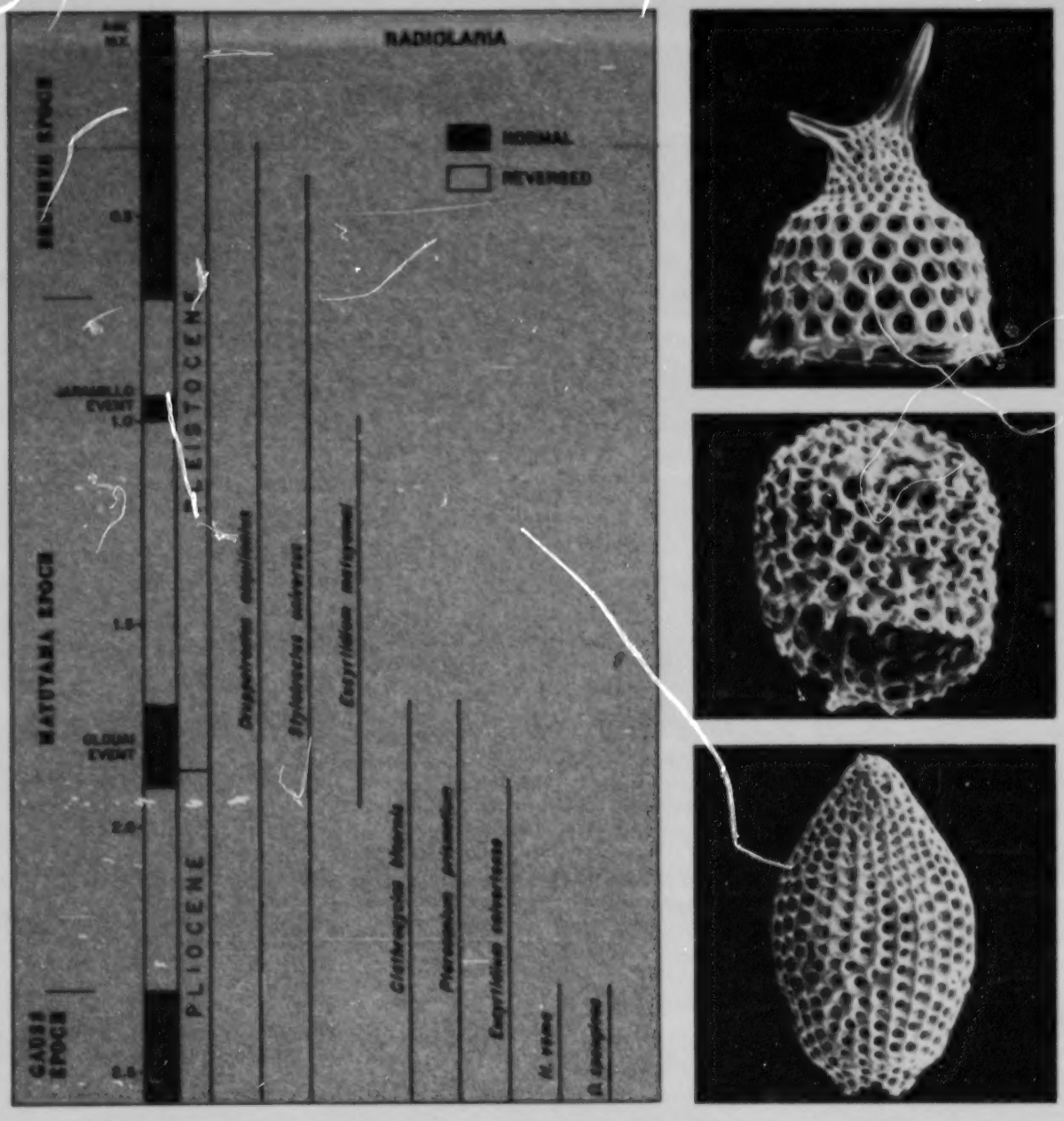
subsurface waters but can be tracked acoustically from a surface ship.

Evolution of Marine Life and the Earth's Magnetic Field

Sediment deposits blanketing the sea floor record effects of the natural processes that formed them and of the evolution of organisms that live in ocean waters. In the past, efforts to decipher this record have been handicapped by the lack of a worldwide time scale on which to base the observations of fossil remains in the sediments. The situation changed dramatically in the mid-1960's when geophysicists showed that the Earth's magnetic field has reversed its polarity frequently over geologic time. Deep sea sediments record these reversals—which occur on the average of about three times each million years—and thereby provide a needed time scale that greatly facilitates interpretation of the developments of oceanic life.

One of the most exciting observations to come from analyses of marine sediments using the magnetic-reversal time scale has been the intriguing correlation between the time of extinction of certain marine protozoans and reversals of the Earth's magnetic field. In a detailed study of these relationships made by J. D. Hays of Columbia University, he found that of eight species of *Radiolaria* that became extinct during the past 2.5 million years, six extinctions occurred close to the times when the Earth's magnetic field was reversing. The probability of this correlation occurring by chance is very small. Dr. Hays and others are extending this work, looking at the relationship of periods of high extinction rates and periods of high and low frequencies of geomagnetic reversals during the last several hundred million years.

The close correlations during recent times suggest that geomagnetic reversals have exerted, directly or indirectly, a selective force in the evolution of these tiny marine animals. How this happens is open to speculation. There have been studies which demonstrate that organisms respond to variations in magnetic fields surrounding them. Other hypotheses relate changes in cosmic rays at the Earth's surface or climatic changes to the magnetic reversals. It is still too early to predict the outcome of these and related continuing investigations, but evidence is mounting that the Earth's magnetic field variations may have played an important role in the development of life on the Earth.



Of eight species of *Radiolaria* that have disappeared in the past 2.5 million years, the extinctions of six closely correlate with times of reversals of the Earth's magnetic field, as shown on the chart. Three of these six fossils are shown at right. From top to bottom: *Clathrocyclas bicornis* Hays; *Desmospyris spongiosa*; and *Eucyrtidium calvertense* Martin, which disappeared from Antarctic waters at the start of the Olduai event, but may still be living in the North Pacific where there is a species that looks very much like it.

ENGINEERING

The primary emphasis of research in the Engineering Division is to increase the understanding of the principles and concepts which are common to and underlie a wide variety of technological problems. Secondarily, the division is concerned with encouraging greater university-industry interaction and cooperation in research. Both of these objectives are important to enable us to make maximum use of the available research manpower in our country and to translate our basic understanding of different phenomena into improved or new technology.

The major administrative change during this year was the reorganization of the Engineering Division. Whereas in past years the division consisted of six separate programs, these were reorganized into three sections, corresponding for the most part to the most important technological areas. Continuous research programs are now part of the same major group and the division's research efforts are in closer balance. The Electrical Sciences and Analysis Section is concerned with research which underlies the electrical, electronic, and optical technologies. The Engineering Chemistry and Energetics Section conducts research programs which are directly related to the technological development and economic growth of the major chemical and physical processing industries. The Mechanics Section is concerned with understanding the underlying principles of mechanics which can lead to improved and new methods for synthesis, analysis, and design applicable to a wide variety of societal and industrial problems.

In addition to its general, unstructured research program, to which the division allocates the major portion of its research funds, it also has encouraged the initiation and development of a number of interuniversity, coherent, cooperative research programs. Such programs often involve cooperation with industrial researchers and thus are of greater benefit and interest to both groups. These programs include research on optical communication systems, advanced automation, the planning and design of tall buildings, wind engineering, ship traffic control, chemical process dynamics, and glass processing. In all of these subjects, the emphasis is on obtaining a better understanding of general concepts. The major difference between these and the unstructured research programs is that the problems are defined more closely so that the grantees and industry representatives can interact with each other and exchange samples, data, and information. The major areas of emphasis in a number of these topics are shown in the table.

The division's program of university-industry workshops also helps to encourage better understanding and cooperation between those two groups by making it possible for each to understand the other's problems, goals, and need for information. The distribution of the workshop reports, which include discussions of the current state of the topic as well as suggestions for the most useful directions for future research, to engineering schools throughout the country make many more engineering faculty members and their students aware of problems outside their own fields and serves as a stimulus for them to apply new techniques and ideas to the problems.

This year the eligibility requirements for the Research Initiation Grants Program were changed, enabling many of the young faculty who had recently worked in industry to submit proposals. This was done by making all assistant professors and instructors eligible for the program, without regard to the doctoral degree or the time the last degree was received.

Data Compression Research Aids Antarctic Rescue

In communication systems, the cost of transmission of information is related in a fundamental way to the rate of information units, called bits per second, required to reproduce the information content, whether that be pictorial as used in television, or voice as used in telephone systems. Hence, it is always desirable to minimize the number of bits required to faithfully reproduce a television picture, for example, because of cost, and minimization is usually necessary because of existing system limitations. Methods of optimally encoding data sources of a general nature, including television pictures as a special case, are being investigated at the University of Southern California with the objective of minimizing the number of bits per second required to encode any given source. These optional methods are called data compression.

As an important application of the data compression ideas developed under the basic research supported by NSF, Lee Davisson of the University of Southern California, under a contract to the National Aeronautics and Space Administration, has developed an experimental data compression system for the National Oceanic and Atmospheric Administration (NOAA) for use on the Wallops Island, Va.-to-Suitland, Md., communications link. Satellite weather television pictures are received at Wallops Island, digitized, and transmitted over the 50,000 bit per second line to Suitland for processing. The original system provided for the pictures to be recorded at Wallops Island and to be examined days later at Suitland and eventually placing the pictures with

University-Industry Workshops

Title	Date	
Optical Computing Systems	September 1972	Carnegie-Mellon University
Productivity in the Durable Goods Industry	September 1972	University of Massachusetts
Electromagnetics of Continuous Media	December 1972	Williamsburg, Va.
Perspectives for Research in Process Simulation	March 1973	Tulane University
Membranes in Separation Processes	April 1973	Case Western Reserve University
Sensors for Automation	April 1973	Massachusetts Institute of Technology
Research Needs and Priorities in Catalysis	April 1973	Houston, Tex.
Automation in Discrete Manufacturing Industry	May 1973	University of Michigan
Future Technological Needs of the U.S. Pulp and Paper Industry	June 1973	SUNY at Syracuse University
Health Care Delivery Systems	June 1973	Easton, Md.
Slender Body Theory	June 1973	University of Michigan

the user. The delay time was necessitated by the limited equipment available for use on the 50,000 bit per second line. However, the availability of the data compression equipment made it possible to put the high-resolution pictures into immediate operational use.

It was just such imagery that made possible the recent emergency support NOAA and the U.S. Navy's Weather Facility gave to the expedition of Jacques Cousteau, the noted sea explorer, which was experiencing great navigational difficulties in the Antarctic in the spring of 1973. Dr. Cousteau's ship had been damaged by ice and an attempt to cross the treacherous Drake Passage at reduced speed in limited visibility was being made. Information concerning icebergs, ice flow, and currents obtained by a high-resolution television camera mounted on a satellite was processed and transmitted back to Dr. Cousteau by the Navy Fleet Facility. This provided the explorer with a near real time picture of his surroundings which averted the immediate danger and would not have been available in time without the existence of the data compression equipment.

Plasma Synthesis of Polycarbon Monofluoride

Great interest in the lubrication properties of a newly developed form of solid carbon monofluoride $(CF_x)_N$ has been generated by lubrication engineers at several Department of Defense agency laboratories. These recent studies have shown that carbon monofluoride as a solid lubricant under extreme conditions such as high or low temperatures, high pressures, or heavy loads is very much superior to graphite or molybdenum disulfide. In addition, workers in both this country and in Japan have concurrently demonstrated a high potential for carbon monofluoride for use as a cathode material in high-energy batteries. Other equally important applications of this material are also being investigated in various academic, governmental, and industrial laboratories.

This recent interest stems from both academic and industrial circles. It has been fostered primarily by the development of new synthetic techniques which derive in part from a process for preparing a similar low-molecular weight fluorinated carbon material from activated charcoal and carbon black. This novel laboratory methodology for producing carbon monofluoride (CMF) by means of a fluorine plasma synthesis route has been developed by Richard J. Lagow and his associates at the Massachusetts Institute of Technology under an NSF grant. In this work the principal investigator produces CMF in a fluidized plasma with graphite as the solid phase and fluorine as the fluidizing gas. This method offers several advantages over previous thermal methods, including low temperatures and lower synthesis energy requirements.

Dr. Lagow reported that measurement revealed the gas temperature of the plasma to be less than 150 degrees C. The amount of energy required to generate the plasma is much less than is required to maintain a furnace of corresponding size in the 600 degrees C-temperature range. Also, it has been proven easier in the laboratory to generate a larger plasma than to keep a large reactor uniformly in the rather narrow temperature range required for the thermal synthesis of the new high-fluorine/carbon ratio CMF. The novel fluidized bed method also avoids the necessity for batch

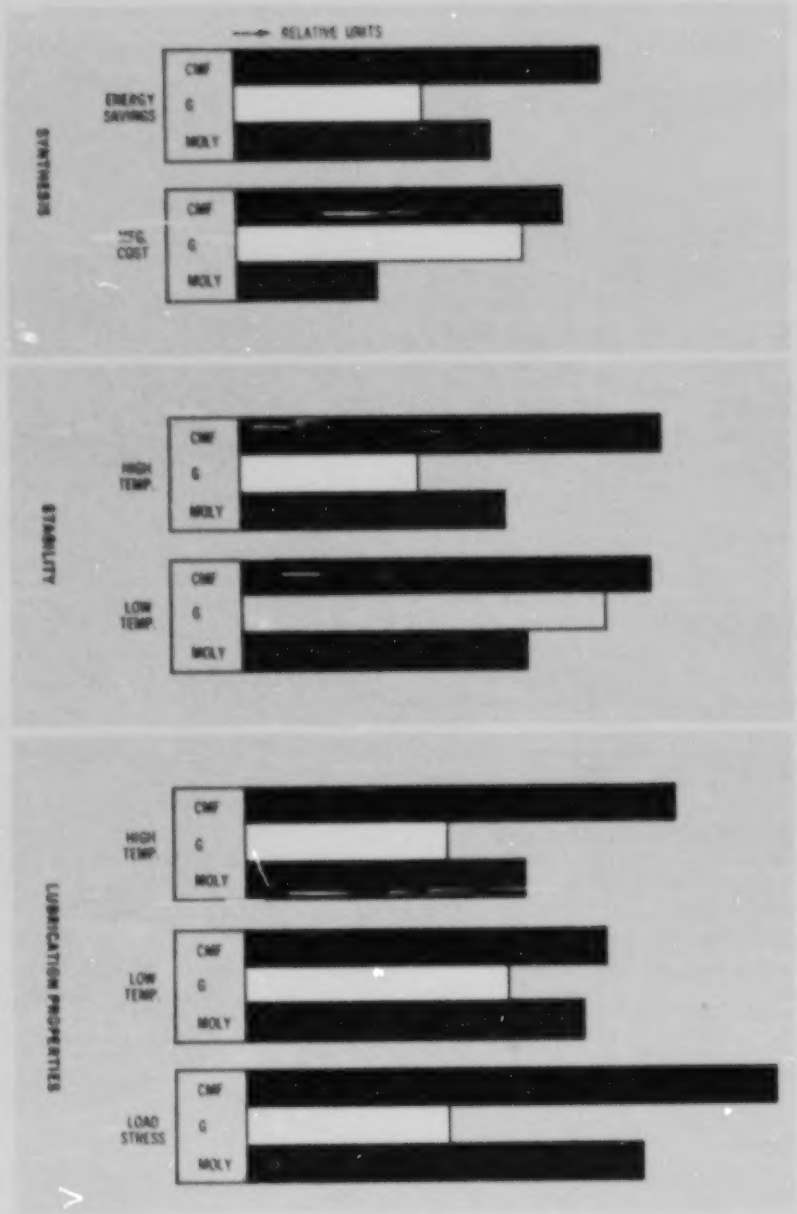
processing since graphite may be continually added, withdrawn, or recycled within the system.

CMF obtained from the plasma fluorination of graphited carbon is at present the most thermally stable polymeric fluorocarbon known. This material has been shown to be indefinitely stable to 600 degrees C and stable for short periods to 800 degrees C. Clearly, this is an enormous advance over similar substances and will find many important industrial and consumer-oriented applications. The technique also provides an example of the use of a fluidized bed plasma reactor design to prepare an industrially important material and demonstrates some of the advantages of the fluorine plasma synthesis process.

The Jet Membrane Separation Process

As attention is focused on the problems in energy and the environment, advances in separation technology become increasingly important. Applications of separation technology involve removal of toxic substances from effluents, separation of chemical species in environmental sensing devices, and, perhaps most importantly, the separation and production of U^{235} fuel from natural uranium.

In terms of energy conservation and environmental impact, a major concern is the large amount of energy required for the separation of the U^{235} isotope from natural uranium for the production of nuclear fuel. For every unit of electtical energy produced from nuclear fuel, approximately .15 units of resource euergy are required in the isotope separation process. Due to the increasing use of nuclear energy, reactor fuel production will represent one of the large single uses of electricity in the United States. It is estimated that by the year 2000, if 50 percent of our electricity is produced by thermal nuclear reactors, approximately 2 percent of all electricity in the United States



This diagram shows the superiority of the newly developed solid carbon monofluoride (CMF) over two other similar materials—graphite (G) and molybdenum sulfide (MOLY)—used in high stress environments.

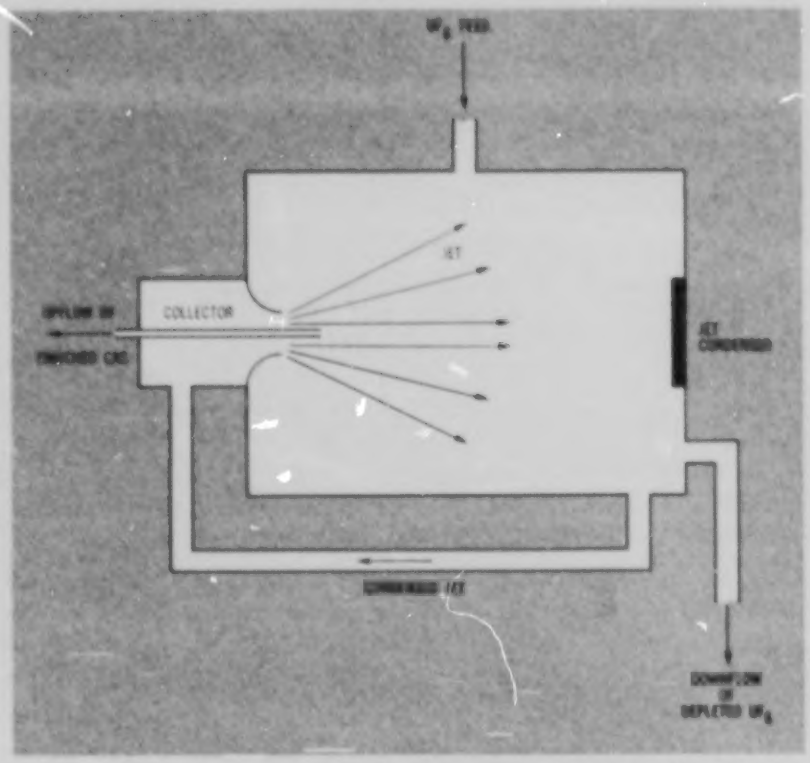
will go into the separation of uranium isotopes.

These statistics provide ample motivation for the application of potentially interesting gaseous separation phenomena to the isotope separation problem.

B. B. Hamel of Drexel University and E. P. Muntz of the University of Southern California have jointly pursued a research project since the fall of 1971 under NSF sponsorship. They have studied a separation phenomena which holds considerable promise for application to the isotope separation problem. The phenomenon on which this approach depends involves the expansion of an easily condensible jet gas into a background region containing the mixture to be separated. The background mixture is at a relatively low pressure. Background molecules diffuse into the jet, forming a thick scattering zone rather than a thin shockwave. It was established from Drs. Muntz and Hamel's earlier work on jet expansion that the background molecules, through interaction with the jet molecules, form an approximation of a undirectional beam directed toward the jet source. If the components of the background gas have different molecular weights or collisions cross-sections, an exponential separation of the components occurs, due to preferential scattering of one component.

This research performed under NSF sponsorship has had a dual thrust. First, both theoretical and experimental work in the past 2 years have confirmed the basic separation mechanisms in this technique.

Secondly, exploratory systems analysis and experiment into the application of this separation technique to the problem of uranium fuel production have been performed. This work has established that the phenomena can produce appreciable mass flow as well as large separation. In addition, it has shown the principal advantages of this technique relative to gaseous diffusion and other competing separation schemes. In the present technique there exist two gas flows within each stage. One is the UF_6 feedstock and enriched material; the other is the jet gas. The jet contains no UF_6, but is essential for the success of the phenomena. Therein lies the main difference between this technique and others. If the jet and UF_6 were to be mechanically pumped, the total energy required per unit of separative capacity would show only a very modest decrease below the value needed in a gaseous diffusion stage. However, for this process, only 10 percent of the flow that must be handled is enriched UF_6; the remaining 90 percent is jet or carrier gas. Since the carrier gas is handled independently of the UF_6, it may be an easily condensible gas, one which can be pumped close to room temperature. The energy for pumping can be low-grade thermal energy—the most interesting energy source in this class would of course be solar heat; another candidate would be powerplant waste heat. The replacement of a major portion of the electrical energy by solar heat in the uranium enrichment process would have a significant impact on fossil fuel use and would result in significant environmental and resource benefits.



This schematic flow diagram shows how a jet membrane process might be used to separate U^{235} fuel from natural uranium at a significant energy savings over current techniques.

SOCIAL SCIENCES

The social sciences are a composite; there are more than half a dozen major social science disciplines specializing in the subject matters which are their principal concern and differing in the methods of investigation which they employ. Although all social sciences have a common core—study of some aspect of human behavior—this degree of specialization is not surprising in view of the complexity of the subject matter and the many institutions and systems that man has created. It is also true that the individual social science disciplines have had varying degrees of success in the effort to develop general theoretical analyses and relatively precise quantitative measures of social behavior. Certain fields, notably economics, psychology, and linguistics, have made important advances toward the goal of achieving an advanced theoretical and quantitative state which permits valid generalization and accurate prediction. Research supported by the Division of Social Sciences is directed toward advancing the scientific development of the social sciences and toward fostering the growth of fundamental knowledge that will be applicable to the problems of tomorrow as well as today.

Distinctive features of the Foundation's program are:

- Development of scientific methodology—so that results are based on better foundations and are replicable.
- Increase of theoretical knowledge—so that integration of findings and true advances are possible.
- More adequate data pools—so that findings are more definitive and generalizable, and so that research costs can be reduced.
- Continuity of effort in fundamental, problem-oriented research—so that a cumulative body of knowledge is achieved.

Work on the improvement of research methods can have short-run as well as long-range consequences. One example is the long-standing question of the degree to which the volume of imports or exports responds to price changes—an important consideration in policy-making on tariffs and other aspects of international trade. Improvements in measuring this relationship for manufactured goods, such as is resulting from research supported at the National Bureau of Economic Research, can provide such guidance on the effects of price changes.

A common problem in the analysis of social science data is the method of handling variables that are categorized (e.g., marital status or race) rather than measured (such as dollars of income or percentage of capacity). James Laing of Carnegie-Mellon University has developed a new method to evaluate scientific hypotheses in these cases. The method insists that the scientist make specific hypotheses for each category of his independent variable. An index then summarizes how well he predicts over all categories separately as well as together. Dr. Laing has used this method to evaluate predictions of coalition formation in small group status games. There are obvious extensions to many situations in which the problem is to decide between several decision strategies. Once the investigator is forced to formalize the decision rules, a typical body of data can be examined to determine the index value for each decision strategy. These can then be evaluated in terms of overall payoff, as well as payoffs for specific subsets of decisions. The index is flexible, easy to compute, extendable to many variables, and has a known sampling distribution for purposes of estimation. It is expected to become widely used within the social sciences, adding additional strength to the presentation of findings.

NSF's program of research in Law and Social Sciences continued in its second year of operation to emphasize the use of social science methods and findings to identify basic forces and concepts that drive and shape the legal system. Among the research topics supported during the year are privacy, the meaning of "fairness" in the legal system, diversity of social function among State supreme courts, processes for controlling inputs and outputs of executive-administrative entities, and the unique structural requirements of rural justice systems. A conference was held at the University of North Carolina on April 11-13, 1973, to assess the present scope and future importance of such non-traditional law-related research. The range of topics now under investigation, the scope of institutional involvement from all sectors of the country, and the potential significance of the research findings now emerging attest to the need for strong, continuous support of collaborative studies by lawyers and social scientists. The program is rapidly becoming a major stimulus for this class of research. Further, its close association with the other social science programs gives the program the capacity to foster projects of high quality which will contribute to the development of both the law and social sciences.

Research in the sociology of science has been a part of the Foundation's activities in sociology, and the history and philosophy of science are special areas of concern and long-standing programs. The Science Policy Research Program brings to the study of science policy a research focus rather than a problem-solving and policy-making orientation (see p. 96), thus helping to build the understanding and knowledge upon which policies can be better formulated. A recent grant to Harvey Sapolsky at the Massachusetts Institute of Technology is supporting

research on the role of the technical adviser and the effective utilization of technical advice in the policy-making process. The two main lines of study concern the problem of how non-experts decide which experts to believe and what elements of their advice to accept; and how the experts formulate their own analyses and judgments and present them to the non-experts. In view of the increasing technological complexity of our environment and the numerous case studies which can be cited in areas such as pesticides, aircraft, and pipelines, a clearer understanding of the advice and decision processes will be of long-range benefit. Another look at advisory mechanisms is underway by Nicholas C. Mullins at Indiana University who is studying the structure of the Federal science advisory system. This project is examining the size and the characteristics of advisory groups over the past 20 years, including the degree to which members circulate from position to position within the structure and the openness of the system to new entrants.

Project LINK

The linkage of national economies is the subject of a large cooperative group research project for which the principal sources of support have been NSF and the International Monetary Fund. The central concept of LINK, as it is called, is to proceed toward a world model on the basis of existing large-scale national econometric models and the world trade matrix. In this system the main international linkages come through the trade accounts, where imports are predicted by each national model and exports are derived via statistics on international trade shares. The accounting criterion in the final solution of the world model maintains that world exports equal imports.

In 1970 and 1971 the project was able to demonstrate that this system could, in fact, yield a numerical solution for world trade. The actual results of these calculations, moreover, were plausible in terms of the recent history of trade flows. In addition, LINK's forecasts of the growth of world trade at a time when a worldwide recession was inducing a slowdown proved to be reasonably good.

Subsequent upheavals in the international monetary order have offered unique opportunities for applying and testing the LINK model. On August 15, 1971, the United States suspended official gold trading and imposed an import surcharge as part of its New Economic Policy. Later, the Smithsonian Conference concluded an agreement on the devaluation of the dollar among other significant international monetary changes. More recently (in February and March 1973) a second wave of devaluations brought further major changes in foreign exchange arrangements. In response to these developments the LINK System of World Trade has been used to analyze balance of payments consequences of both actual and hypothetical configurations of exchange rates. These simulations called to the attention of policy-makers a number of danger signals, which more accurately than other available prognoses foresaw the critical trade deficits of the United States.

Lawrence Klein of the University of Pennsylvania, the chief architect of LINK, summarizes its history and prospects when he notes that "If the first years of LINK research have been mainly concerned with defining the trade/transmission problem, specifying the statistical systems, and obtaining meaningful simulation solutions for the world economy, the second phase will turn increasingly towards analysis of capital flows and international financial relationships." To study these questions effectively each country or area model needs a balance-of-payments submodel, which in turn requires a well-articulated domestic monetary sector. To help fill these gaps NSF's Economics Program in the past year has initiated other cooperative research endeavors that focus on the flow-of-funds. Thus, Project LINK should increasingly be the beneficiary of systematic related research while it continues to make its own methodological contributions and highly relevant applications.

Astro-Archaeology

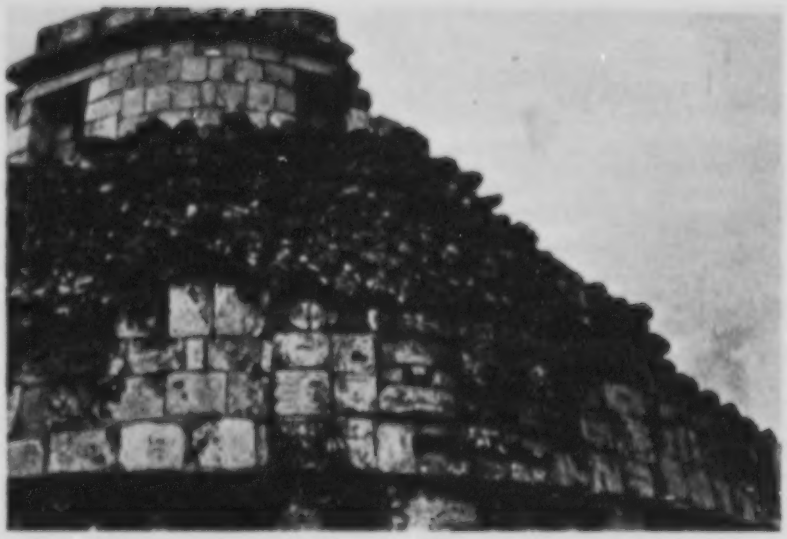
Probably the most rapidly blossoming interest in archaeological science in recent years is astro-archaeology, or archaeo-astronomy. The aim of astro-archaeological investigations is to bring to bear collaborative efforts of professional astronomers and archaeologists (as well as in some cases structural engineers) on particular architectural remains—most of which have been well reported archaeologically. The objective is to provide fresh understanding of the beliefs of prehistoric peoples who designed and built ancient monuments that are presumed to have served astronomical or religio-astronomical purposes.

Anthony F. Aveni of Colgate University, an astronomer, has re-examined the nature of postulated astronomical alignments of prehistoric structures at Mayan ceremonial sites in Yucatan and at sites of similar age in the Oaxaca area. Architectural features at these sites have long been suspected of serving astronomical functions, but until now modern astronomical techniques and observational data have not been used to confirm that they actually were intended for celestial observation. Using standard techniques of astronomy, Dr. Aveni has concentrated on projecting backwards from contemporary sitings of celestial phenomena to determine their ancient rise-set azimuths. These can be precisely calculated from computer generated tables for the observation positions on the ground. The ancient rise-set azimuths are then related to the investigator's carefully measured

compass alignments of archaeological structures.

Dr. Aveni has developed his own azimuthal tables, corrected for local atmospheric distortion, altitude, and site elevation, covering all latitudes between 60 degrees north and 60 degrees south for the period from 1500 B.C. to A.D. 1500. The time span is sufficient to include the dates of all astro-archaeologically interesting sites in Meso-America. Field procedures involve correcting true north on existing site maps from published magnetic declination tables. Site lines accurate to 1 minute of arc have been laid out. It is assumed by archaeologists that ancient peoples established astronomical alignments with reference to the apparent horizon, so Dr. Aveni has prepared measurements of the altitude of the skyline at 1/2-degree intervals of azimuth. Also, he is ascertaining the azimuth with respect to the angle between the Sun and the wall of structures in relation to the rise position of certain stars and the solar zenith passage. It appears that suspected astronomical observatories were built with siting perpendiculars and shaft openings aimed at these celestial positions.

Dr. Aveni infers that the buildings were intentionally oriented to permit observing celestial events that marked major transition times of the year. For example, the rise of the star Capella appears to have coincided with the dates of passage of the Sun through the zenith at the latitude of the Oaxaca site. Appearance of the star Capella at the horizon siting indicated by the building's wall alignment probably presaged the passage of the Sun at zenith that day, and accordingly probably served to mark the length of the year (i.e., the year was reckoned from the day the heliacal zenith was seen in the building's shaft opening to the next occurrence of the same observation). Much of this interpretation of the astro-archaeological significance of building alignments has still to be proven beyond question. However, evidence accumulated to date indicates that architectural features of the kinds described are frequent enough that they are probably not fortuitous.



This cylindrical Mayan building, El Caracol, in northern Yucatan may have functioned as an astronomical observatory. Measurements indicate the two rectangular passageways could have been used to sight astronomical objects as they set along the western horizon at different times of the year.

Environmental Dispositions and the Creation of Environments

An inevitable problem that most people face when trying to evaluate the consequences of certain kinds of environmental policies is visualizing what the proposed alternatives would really look like. Recognizing this, a group of architects, planners, and social psychologists at the University of California, Berkeley, is creating a dynamic environmental simulator that will enable people to "walk" or "drive" through small three-dimensional scale models of urban, suburban, and natural environments.

A remotely guided television camera, controlled by computer, is made to move through scale models of a given environment. The camera projects continuous eye-level views on closed circuit television screens in the laboratory. These simulated auto tours through miniature environments can then be displayed to large audiences.

The simulator will be used to provide vivid and accurate previews of alternative environmental futures. Conceivably, scale models of entire cities and counties could be constructed and permanently housed in large warehouses for use in this way. Then whenever any alteration is proposed in the environment, that change could be represented on the model and authorities and the public could take simulated tours through the modified model. Before this can be done, however, it must first be shown that impressions gained in these eye-level tours through scale models are sufficiently similar to the impressions that would be formed during an actual tour through the real environment. A host of similar questions arises with respect to the

stability of preview impressions and of the preferences and values of the subjects who are asked to deliver such evaluations. The team is now conducting a broad program of research at the facility to develop "truth in simulation" procedures and to study by scientific methods the underlying characteristics of a technique whose coming use in planning and public decision-making seems very likely.

Architects, planners, and social psychologists at the University of California, Berkeley, are developing this simulator, viewed through a moving street-level camera, to help people preview the effects of alternative environmental actions.

MATERIALS RESEARCH

Research in materials is increasingly recognized as essential in the solution of most problems in the modern technology. The search for fundamental knowledge in this area involves solid state chemists and physicists, metallurgists, ceramists, and engineers. It is in part because of this breadth that a significant new effort of wide interest was funded in fiscal year 1973 through the Division of Materials Research. The project involves the construction and operation of a facility to use the synchrotron radiation from the storage ring (SPEAR) associated with the linear accelerator at Stanford University. The radiation, which is an extremely intense continuum of highly polarized, well-focused, very short bursts of photons, has applications in aeronomy (upper atmosphere studies), biology, atomic and molecular physics, chemistry, and solid state science. It will be available to all qualified users.

In its first full year of responsibility for the 12 materials research laboratories (MRLs) the Materials Research Laboratory Section has seen an increase in both the administrative and the technical strength of the program. A policy statement was issued which outlines future plans including the introduction of a competitive element for current MRLs and potential MRLs seeking support. Two new awards, one to the University of Massachusetts for

work on two phase polymers and one to Carnegie-Mellon University for joining research, broaden the overall program. The core support provided by the MRL Section complements the project system and has resulted in significant advances. As an example, it has facilitated the studies of the conductivity of organic materials at the University of Pennsylvania. Increasing coordination and cooperation in the core and project support, as well as among the MRLs within the program, has been evident and encouraging.

Increased support to the National Magnet Laboratory has made it possible to make the facility available to visitors for 70 hours a week rather than 40 hours. Research at the NML has produced some of the first basic experiments in the areas of laser-induced gas breakdown, plasma heating, and plasma containment in a magnetic field. Also of significance has been the development of a broad band radiation source, a thousand times more intense than a conventional source, bridging the "gap" between the infrared and microwave regions of the electromagnetic spectrum.

The Solid State Chemistry and Polymer Science Program is continuing at about double the level supported by the Chemistry Section in fiscal year 1971, and is nearly equally divided between solid state chemistry and polymers. To help plan future polymer support, a workshop was held in Washington in fiscal year 1973, with presentations from leading scientists and engineers. As a follow-up, a selected group developed suggestions for promising directions in research. A similar workshop is planned for solid state chemistry and the ceramics community in fiscal year 1974.

The Engineering Materials Program increased its support of research in extractive metallurgy, which is critical to problems of balance of trade, energy, and the environment. The program has continued to support research covering the broad range of materials, including polymers, ceramics, metals, and alloys. The coherent areas in hard materials and biomaterials have been increasingly productive, and the grantee meetings with industrial representatives have been most successful. A workshop on nondestructive characterization of materials was held at the Rockwell International Science Center to assess the basic problem areas impeding progress, and to determine future research needs.

The Solid State and Low Temperature Physics Program continued its support of a broad spectrum of fundamental research on a wide variety of materials, and strengthened its support of several important areas. There was a marked increase in high-quality proposals for investigations on organic materials, the relationship between structure and superconductivity, and in new approaches to surface science. The recent observation of two new phase transitions in solid-liquid He^3 in the region of 0.002 degrees K. has spurred even more interest in ultra-low temperature physics. Topical symposia are proving excellent vehicles for stimulating communication and cooperation between active research groups. In the past year, symposia on Monolayer and Submonolayer Helium Films and on Surface and Guided Waves were supported, the latter in conjunction with the Engineering Division. Symposia on both organic materials and on the connection between lattice instabilities and superconductivity are planned for the coming year.

Controlled Microphase Segregation

High polymer molecules (long chains of atoms chemically bonded together) may be either thermoplastic, (i.e., they are essentially linear and flow when melted) or thermosetting, (i.e., they are crosslinked into three-dimensional networks and often decomposed before melting). An important subclass of the thermosetting type is the rubbers (elastomers) in which the chains are mobile but cannot flow because of the crosslinks. An important advantage of the thermoplastic materials is the speed, i.e., low cost, of forming shaped objects. Elastomeric objects do not share this property to the same degree since they must be crosslinked after forming. Polymer chemists have recently found ways of combining thermoplastic and elastomeric properties by making block copolymers.

Most block copolymers are made up of two different units, e.g., A and B, arranged in long sequences or blocks within the same molecule. Homopolymers of all A or all B are usually incompatible so the block copolymers frequently separate into two phases. However, since the sequences of A and B are attached to the same molecule, the resulting phase separations are small, i.e., microphases of the order of 100-300 angstrom units, and are connected by strong covalent bonds.

The technical uses of block copolymers are closely related to these covalently bonded microphases. When blocks that can crystallize or form glassy microphases are present in a rubbery matrix, a thermoplastic elastomer results. The crystalline or glassy microphases serve as crosslinks for the rubbery matrix. However, unlike chemical crosslinks in a vulcanized rubber, these microphases can be "melted" and objects may be shaped or reshaped upon heating.

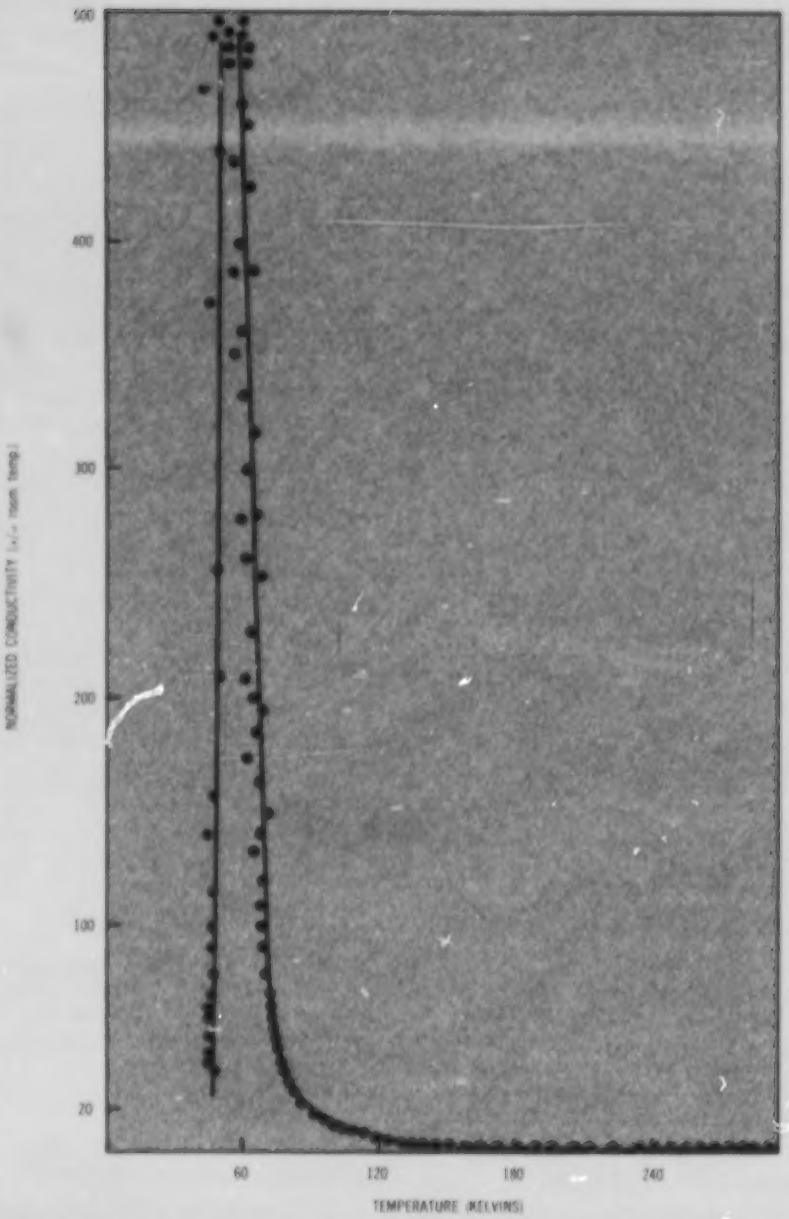
A number of projects dealing with various aspects of this microphase segregation are supported by NSF. For example, a group at the University of Akron is synthesizing and characterizing the co-polymers which result from combining different homopolymer blocks of varying lengths. Sonja Krause at Rensselaer Polytechnic Institute is investigating theoretically and experimentally the conditions under which phase separation occurs. A group at the University of Tennessee is beginning an investigation of the effect of processing upon the

morphology and physical properties, and the major thrust of the new materials research laboratory at the University of Massachusetts includes work in this area. A much clearer understanding of the fundamentals of microphase separation and its relationship to molecular structure and physical properties is beginning to emerge. For example, block co-polymers can be either diblock, A-B, or triblock, A-B-A, where either the A or B acts as the crosslinking or "hard" segment. Microphase segregation is critically dependent upon composition and molecular length of each segment, the interaction parameter between the two homopolymers A and B, the presence of solvents, as well as melt and shear history. Theoretical or phenomenological descriptions of these relationships are of considerable importance to the practical application of these materials.

Electronic Properties of Organic Charge Transfer Salts

The concept of utilizing the infinite variety of organic chemistry to synthesize materials of desired properties has assumed increasing scientific and technologic importance over the years and has yielded such remarkable developments as polymers, plastics, and certain modern pharmaceuticals. However, it is only recently that solid state physics and synthetic organic chemistry have joined forces to explore the electronic and optical properties of tailor-made organic materials.

Organic salts based on the molecule tetracyanoquinodimethane (TCNQ) comprise one such class of intriguing systems currently under investigation from this joint materials research point of view. TCNQ, when combined with molecules such as n-methylphenazinium (NMP) or tetrathiofulvalene (TTF), crystallizes into alternating one-dimensional chains of each molecule. These materials are known as charge-transfer salts because conduction electrons are furnished to the TCNQ chains by the transfer of electronic charge from neighboring NMP or TTF chains. Since the spacing of adjacent molecules along a chain is smaller than that between chains, each chain can be considered as a one-dimensional crystalline lattice. The one-



This graph of electrical conductivity versus temperature of a crystal of TTF-TCNQ, an organic charge-transfer salt, suggests the possibility of achieving superconductivity at much higher temperatures than now possible in metallic systems.

dimensional character of the lattice is a simplifying feature of considerable scientific interest which is also reflected in a corresponding one-dimensional electronic structure. Thus, for example, conduction of electrical current proceeds almost exclusively along the chain direction. These unique organic materials are found to exhibit a variety of electrical and magnetic properties. The system NMP-TCNQ, for example undergoes an electronic phase transition from an insulating antiferromagnetic state to one of "metallic" conduction as the temperature is raised through 200 degrees K.

During the past year, a dramatic transition in the electrical conductivity having possible implications for high temperature superconductivity has been discovered in the charge-transfer salt TTF-TCNQ by A.J. Heeger, A. Garito, and coworkers at the University of Pennsylvania. Related studies on this system are also being carried out by David Cowan and J. Perlstein at the Johns Hopkins University and at a number of other laboratories. The electrical conductivity of a selected crystal of TTF-TCNQ as a function of temperature is shown in the figure. A poor "metallic" conductor at room temperature, TTF-TCNQ exhibits a 500-fold increase in conductivity to that approximating copper as the temperature is lowered below 90 degrees K. Although the effect is seen in only a small fraction of the crystals studied, difficulties with sample homogeneity and electrical contacts suggest that the intrinsic conductivity may in fact be much larger. The collapse of the highly conducting state as the temperature is further decreased appears to result from a structural instability in the one-dimensional lattice.

The dramatic increase in the conductivity of TTF-TCNQ has been tentatively attributed by the Pennsylvania group to the onset of a superconducting transition at 58 degrees K., and efforts are currently under way to stabilize the high conductivity phase using various techniques. Since the highest temperature at which superconductivity has been observed in metallic systems is approximately 20 degrees K., the possibility of achieving superconductivity at much higher temperatures in the organic charge-transfer salts has stimulated intense theoretical and experimental activity. Even if the interpretation of the effect in terms of a superconducting transition should prove to be incorrect, this work will have focused worldwide scientific attention on a relatively unexplored and exciting new area of materials science.

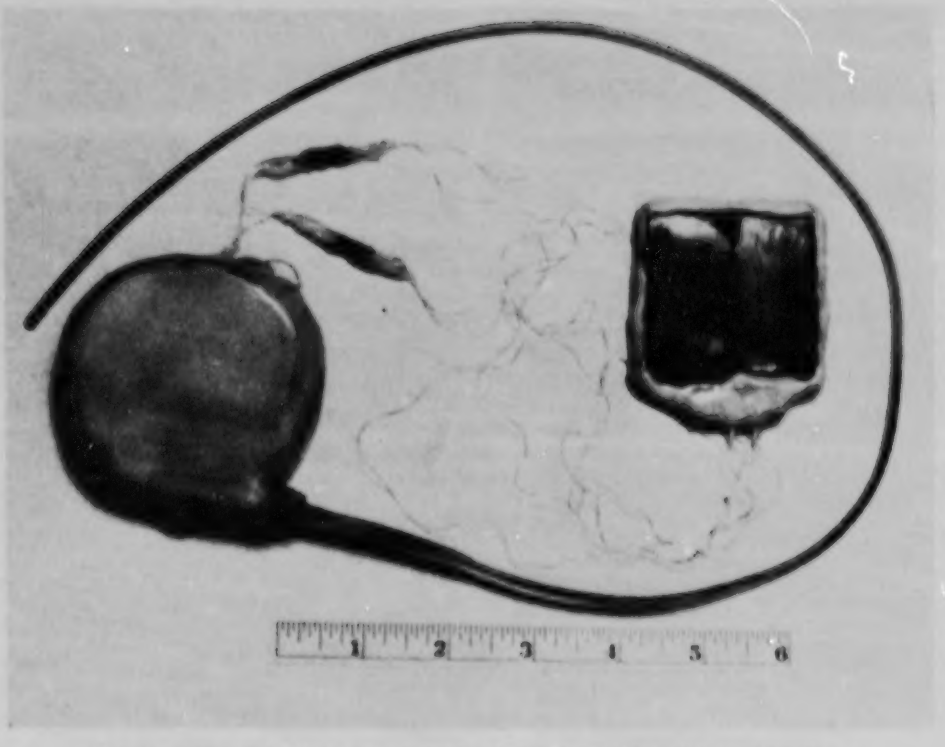
New Power Sources for Pacemakers

Pacemakers, biotelemeters, and stimulators require long-term implantable power sources in the microwatt range. Over 75,000 Americans, most in their sixties and seventies, rely on the timed electrical pulse delivered by pacemakers to provide the heart stimulation they have lost due to heart block. Present pacemakers powered by mercury cells must be replaced every 24 months with surgical risk and inconvenience. A low cost, long shelf life energy source with a potential lifetime exceeding 10 years is the biogalvanic hybrid cell consisting of a sacrificial anode and a fuel cell-type catalytic cathode. At Drexel University in Philadelphia, a biogalvanic hybrid cell consisting of an aluminum anode and porous palladium black cathode has been powering a commercial pacemaker which has been pacing a dog with complete atrioventricular block without significant adverse effects. This research project is an interdisciplinary effort under the leadership of Richard Beard and Stephen Dubin.

The basic materials problems encountered with commercially available fuel cell electrodes include: electrode polarization, high corrosion rate of anodic materials, low potential lifetime, and poor foreign body reaction. Electrode polarization lowers the available power from the implantable electrodes. Electrochemical methods using galvanostatic and potentiostatic techniques are currently being used to study electrode polarization of candidate porous catalytic materials. Surface areas and pore structures of the more promising catalytic electrodes are characterized using an absorption procedure and scanning electron microscopy.

Since a high corrosion rate can be a distinct disadvantage to a long-term power source, *in vivo* corrosion studies are underway on anode materials. Clinical, hematological, and histopathologic studies on dogs with implanted hybrid power sources for periods up to 9 months have yielded favorable results and constitute an important section of the research underway.

Hybrid cells made of porous catalytic electrodes have a power output up to six times greater than that of commercially available fuel cell electrodes. Compared with the commercial fuel cell cathode, porous electrodes have shown a much better foreign body reaction with the body tissue surrounding the implants resulting in a greatly improved *in vivo* performance.



This experimental biogalvanic hybrid cell (at the right), used in a heart pacemaker, promises to provide reliable power six times longer than conventional cells without the corrosion problems associated with most long-term power sources.

COMPUTING ACTIVITIES

Even though the first modern computer was invented only 27 years ago, today the computer touches almost every facet of national activity. Scientists routinely use the computer to solve large mathematical problems and to simulate experiments that would not be feasible without the computer. Computers are used to control non-intelligent machines and as aids to human traffic controllers. Modern consumers rely on the information processing capability of the computer for bookkeeping, billing, and inventory control. As the cost and size of computers decrease, the number of users and uses will become even more pervasive.

The Office of Computing Activities supports basic research on the underlying concepts and methodologies employed by computer systems and computer users. The greatest percentage of support is for fundamental research in computer science and engineering. Research projects include development of new system architectures and computer languages as well as the further development of a theoretical understanding of computer science. Thus, the research supported will make possible computer systems of the future which will be even more useful than today's systems.

A parallel activity supports research on innovative use of computer science and technology by scientific researchers. The results are advances in research methodology, which enable these scientists to be more productive and to conduct research that might otherwise not be possible. Two new programs—Software Quality Research, and Networking for Science—were established in 1973. Networking is an extremely attractive approach for many researchers who need access to geographically distributed research resources which in some instances would be beyond the financial reach of a given insitution.

A new activity—Computer Impact on Society—was created in November 1972. This program supports studies and meetings to define the impact of the computer on the individual and organizations. As this program grows, basic research on computer systems used by society will be supported.

In fiscal year 1973 the Computer Innovation in Education programs were transferred to NSF's Education Directorate. This change permits continued encouragement for computer applications in education while adding the additional educational expertise required for the successful introduction of computer technology to research in new educational techniques.

The organizational changes that occurred in fiscal year 1973 are in recognition of new developments in computing. With those changes the Office of Computing Activities was transferred in May 1973 from National and International Programs to Scientific Research Project Support. Examples from the three major areas of support are briefly described here.

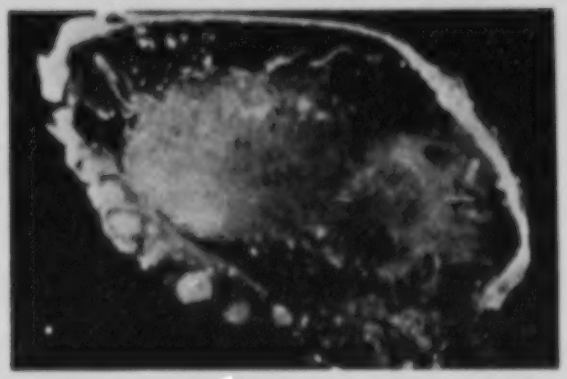
Construction of 3-D Models from 2-D Images

Many research disciplines share the problem of producing a three-dimensional model from two-dimensional images such as X-rays, microscope pictures, or electron microscopes. The three-dimensional model is necessary to show the true shape of objects, their proximity to each other, and the general integrated environment. Several researchers are attacking this problem with various techniques.

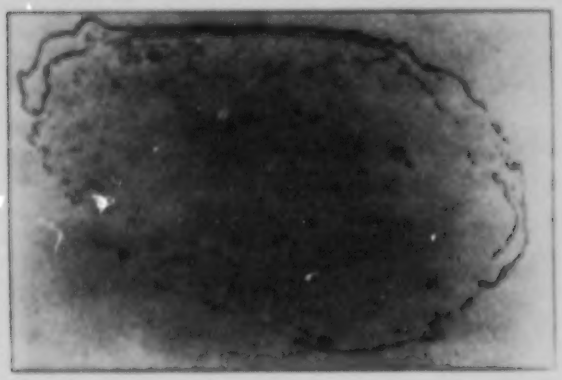
D. R. Reddy at Carnegie-Mellon University has been exploring computer techniques for determination and modeling of the three-dimensional structure of a lobster's neuronal network. A block of tissue is removed from a nerve center of the lobster and a chemical dye is injected into one or more nerve cells in the tissue. The block is then sliced into thin sections which are examined under a microscope. Each microscope image is automatically digitized by dividing it into an array of tiny areas with a number assigned to each area according to its light intensity. The computer stores the numbers and improves the image through various operations, such as contrast enhancement, "noise" reduction, and detection of outlines, then analyzes the boundaries from each image relative to adjacent images. The purpose of these computerized manipulations of the two-dimensional images is to extract the relevant neuronal landmarks. The boundaries of large structures are approximated by a series of straight lines and the smaller structures by circles. Then the computer reconstructs a model of the shape of the nerve cells in three dimensions and displays the cells as they would appear from any viewing angle.

Quantitative information about fiber sizes, distances, and connections are readily obtained. In addition, the computer can assemble two or more reconstructed neurons from different experiments into a single model and perform appropriate quantitative analyses. For neurophysiologists who have been observing and measuring nerve structures for many years, the computer promises an enormous saving in labor and improvement in results of the reconstruction efforts. Though in its present unfinished form the system is useful only in the hands of trained computer scientists; in its finished form, says Dr. Reddy, biologists untrained in the computer sciences will be able to use the system.

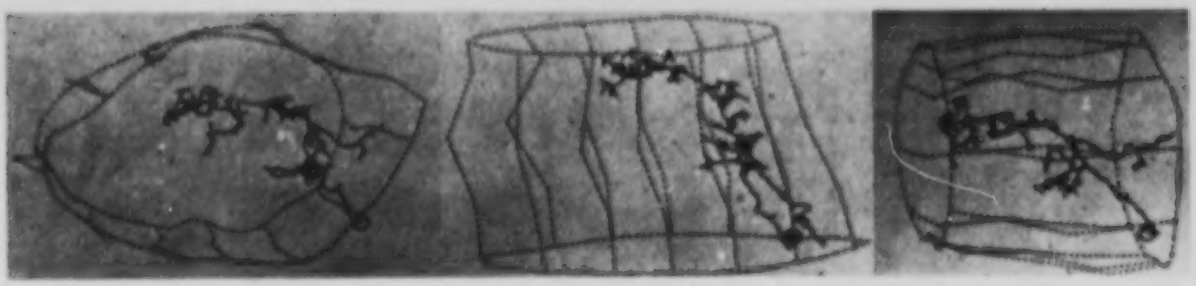
Photomicrograph of Lobster Motor Nerve



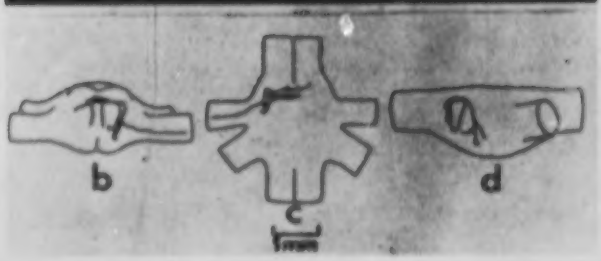
Lobster Motor Nerve After Edge Detection



Computed 3-D Model of a Lobster Nerve in 3 Views



Lobster Motor Nerve Reconstructed From Computer Output



A computer technique developed by D. R. Reddy at Carnegie-Mellon University for producing three-dimensional models from two-dimensional images goes through the following steps: A set of photomicrographs is made of a nerve cell (in this case from a lobster); the computer digitizes and enhances the image; the computer compares adjacent images to produce a three-dimensional representation; and an artist draws a picture of the cell.

Privacy: Data Security and Access

The continued rapid growth of the use of computers and computer-based data banks has been paralleled by a rising social concern over potential threats to personal privacy and the security of the data stored in these systems. Recent headlined criminal cases charging fraudulent manipulation of computer-based corporate financial data raise new questions about the security of computer systems. A host of political, economic, and legal issues—as well as several technological problems which are both scientifically challenging and socially important—surround the problems of privacy and security. The Office of Computing Activities supported a series of projects this year to better illuminate the technological issues and to initiate research on the more important ones.

One such problem is how to more effectively provide confidentiality to data and program files stored in a computer system used by a large number of people. Lance Hoffman of the University of California, Berkeley, is studying the computer time and cost requirements for providing file security by a variety of methods, and is incorporating his findings in the design of new computer programming languages.

The issue of privacy and security was discussed at a conference held at Stanford University in June 1973. The meeting, jointly sponsored by the American Federation of Information Processing Societies and the Stanford Law School, brought practicing lawyers, legal scholars, and computer scientists together to discuss ways in which the computer and the law affect each other.

Providing for citizen access to the computer systems and to data banks being used in Government planning and administration is the opposite side of the privacy/security coin. The Comprehensive Planning Organization (CPO) of San Diego County is exploring mechanisms by which non-technical citizens and interest groups can gain access to and better understand the automated planning tools—such as computer-based data and simulations for regional planning activities—used by CPO. By incorporating various community value systems into the evaluation phase of the model, the computer can allow CPO to provide city administrators with information about the desirability of alternative development plans.

Computer Reliability

In many aspects the study of computer systems is the study of complexity. Consider the complexity of a computer program such as a well-known program containing 2.7 million individual instructions designed to carry out hundreds of thousands of individual tasks. The number of combinations of possible control paths in such a system is very large, although finite. Since it is not presently possible to test all permissible combinations of tasks in such systems, how can one verify their correctness?

Several approaches are being taken to solve this problem. One is to design programming languages in which the tasks are so specified as to inhibit the interaction of tasks. Jacob T. Schwartz, Courant Institute of Mathematical Science, New York University, has designed a language that enables the programmer to define tasks similar to the way a mathematician states a theorem, thus controlling the ways tasks can interact. Mark B. Wells and James H. Morris at the Los Alamos Scientific Laboratories, working with Michael Melkanoff at the University of California, Los Angeles, have developed a different, very high level programming language that controls the interaction between tasks through carefully designed mechanisms.

Other investigators are studying techniques by which a program might be proven correct. Starting with assertions that can be proved true for a given task, the truth of corresponding assertions for subsequent tasks can be determined. When the truth of the assertions for all permissible combinations of tasks can be shown, the program is proved correct. To date these techniques, inspired by Robert W. Floyd at Stanford University, have been applied only to small programs.

In addition to knowing that a program is correct, it is vital to know that the computer will correctly carry out the program instructions. Algirdas Avizienis at the University of California, Los Angeles, is studying ways to design computers which perform reliably even when components fail. His goal is a fault-tolerant computer which can execute its entire set of programs correctly even in the presence of faults in the computer system. Research results and design experience have shown that the systematic introduction of protective redundancy (through the use of added hardware, software, and the repetition of tasks) can avoid or at least decrease computing disruptions caused by hardware failures. Current research is refining these procedures to increase reliability.

National and International Programs

National and International Programs

Programs in the Directorate for National and International Programs are characterized by diversity and intensive participation by NSF management. Often they involve field activities and large logistics components. Generally, they are designed to meet specific objectives and to achieve results that satisfy immediate and future needs of society.

Mounting concern over the quality of the marine environment and depletion of mineral resources indicate that far better knowledge about the oceans of the world is essential to our well-being. Through the programs of the International Decade of Ocean Exploration, intensive studies are providing a better understanding of the degree to which our oceans have been polluted, how the oceans affect our weather and climate, and the prospects of finding and extracting resources from the world's oceans. The Ocean Sediment Coring Program continues to contribute to our knowledge of the origin and dynamics of oceanic basins through the drilling activities of the *Glomar Challenger*. Analysis of cores, taken from hundreds of locations throughout the world, is producing a wealth of information on the evolution of ocean basins, past climates, seafloor spreading and continental drift, and potential source beds for oil and minerals.

Research in the polar regions, although costly and laborious, is a necessary part of the study of the total world environment. In fact, an understanding of world weather and climate will be achieved only when the two principal heat sinks—the Arctic and the Antarctic—have been studied on sufficient scale and in sufficient detail to make the data therefrom meaningful. Similarly, pictures of global tectonics or ocean circulation, for example, would be meaningless without data from the polar regions.

To advance our understanding of the universe and its evolution, NSF supports four National Research Centers which provide "cutting edge" facilities and instrumentation for investigations in astronomy. The initial steps were taken toward the construction of the Very Large Array, an eye to the outer reaches of the universe, having potential for significant breakthroughs in radio astronomy.

Investigations based at the National Center for Atmospheric Research could have profound effects on our society. Two projects that warrant special mention are the development of a global atmospheric circulation model for use in long-range weather forecasting, and a study of means to suppress severe hail storms.

Cooperation in science is recognized as an avenue towards better relations among nations and as a practical means to further U.S. foreign policy objectives. The National and International Programs Directorate, acting as the Foundation's "foreign office," has continued to explore and exploit opportunities for mutually beneficial cooperative scientific activities with other nations. These activities increased considerably during the past year, and the Foundation's role in international science activities is likely to continue to expand in the years to come.

The dependence of our science- and technology-oriented society on communications is an undisputed fact. The Science Information Service continued to play a national role in this area, providing support and coordination of scientific and technological information systems and services. During the year, the Office of Computing Activities was transferred to the Research Directorate in order to provide better integration with its research project support. Finally, a new program, Research Management Improvement, was added to the responsibilities of the National and International Programs Directorate.

Table 3
National and Special Research Programs Awards
Fiscal Years 1971, 1972 and 1973

(Dollars in millions)

	Fiscal Year 1971		Fiscal Year 1972		Fiscal Year 1973	
	Number	Amount	Number	Amount	Number	Amount
International Biological Program	57	$ 7.50	58	$ 9.44	30	$ 9.20
Global Atmospheric Research Program	31	1.90	37	2.39	55	3.45
International Decade of Ocean Exploration	44	15.00	102	19.67	92	16.94
Arctic Research Program	32	2.00	61	3.54	62	3.43
U.S. Antarctic Research Program	121	7.76	139	27.00	130	44.00**
Oceanographic Facilities and Support	23	8.57	65	18.52	62	10.99
Ocean Sediment Coring Program	8	7.13	9	9.26	24	9.59
1973 Solar Eclipse Support	0	0	2	.06	10	.68
Experimental R&D Incentives Program*	0	0	0	0	75	11.89
National R&D Assessment Program*	0	0	0	0	50	2.79
Total	294	$49.86	457	$85.88	591	$117.46

* Program established in August 1972

** Includes Supplemental Appropriation, $19.74 million, for procurement of three ski-equipped aircraft

NATIONAL AND SPECIAL RESEARCH PROGRAMS

National and Special Research Programs of the Foundation are major efforts of research or research support of such broad scope that extensive coordination of planning, management, funding, and logistics is essential to effective program performance. These programs may be characterized by inclusion of one or more of the following elements: international cooperation, coordination with other agencies of Government, a relationship to a specific geographic region, or interdisciplinary scientific investigations.

INTERNATIONAL BIOLOGICAL PROGRAM*

The International Biological Program (IBP), for which the National Science Foundation is the lead agency for the United States, was organized to investigate how ecosystems function and to determine man's relation to them. In the United States, these two aspects correspond to two programmatic components: Environmental Management and Human Adaptability.

The greatest part of the work on the functioning of ecosystems has been in five distinct types of habitats or vegetation forms or biomes—grasslands, desert, coniferous forest, deciduous forest, and tundra. In addition, the origin and structure of ecosystems is being studied by comparing similar vegetation types in North and South America—Mediterranean scrub, and desert scrub—and by examining island ecosystems in Hawaii.

*Although administered by the Research Directorate, IBP is included here because of its identification as one of the Foundation's National and Special Research Programs.

The landscape represents many different things to different persons. To the ecologists it appears as a pattern of interdependent units, or ecosystems, all derived by evolutionary processes and moderated by time, climate, and soil type. Like other organisms, man interacts with the components of ecosystems, though often with far greater and more far-reaching force than other organisms. To maintain the quality of his environment, man's interactions must be interpreted in light of the internal dynamic and regulating mechanisms of these ecosystems.

Among the obvious but incompletely understood modes of maintaining stability are the cycle of nutrient materials and the flow of energy. In each of the biome projects, serious efforts have been made to characterize the cycles of major nutrient elements by investigating ecosystem reservoirs, pathways of transfer, and rates of movement. For example, the different cycles of nitrogen are illustrated for the desert and forest ecosystems.

Interbiome comparisons undertaken in the past year have demonstrated that the desert has markedly higher rates of nitrogen fixation than the forest, primarily because of the blue-green algae encrusting the desert soil surface. Much of the nitrogen fixed by these algae, however, is lost as gaseous ammonia because of the alkaline nature of desert soils. Approximately 70 percent of this nitrogen is recycled to the atmosphere, never becoming available for plant growth. In contrast to this open cycle, the deciduous forest has now been shown to internalize its nitrogen cycle. Both the fixing of nitrogen and its release are low compared to the desert, but the inputs from the atmosphere are retained by the abundant organic detritus, and a large proportion becomes available for plant nutrition.

Although carbon can be treated as simply another element cycling through the environment like nitrogen, deeper insight can be gained into the functioning of ecosystems by constructing budgets for carbon because it is the principal medium for movement of energy through the system. Thus in the green plant, photosynthesis can be measured as the rate of uptake of carbon and its utilization in production of carbohydrates. The eating of grass and leaves transfers carbon to animals, and plant and animal respiration returns carbon to the atmosphere as carbon dioxide. Detailed budgets, and transfer rates from studies in different systems permits instructive new comparisons.

The comparative functioning of four different ecosystems—deciduous forest, coniferous forest, prairie, and tundra—is seen in the table. Total photosynthesis occurs in decreasing order reading from left to right in the table and is determined by the lengths of growing seasons as well as the biomass or standing crop. Respiration by plants, the cost of production, is influenced by the temperature and length of the growing season and the mass of supporting tissue. The net gain obtained by subtracting respiration from photosynthesis shows similar patterns in all the temperature ecosystems, but is markedly different in the tundra. The tundra is also aberrant because of the very low respiration rate of its decomposers, largely a consequence of reduced temperatures and the low total biomass of the system.

The object of these new efforts to compare ecosystems has not been to show that all of them are similar, but that the consistent patterns found can be extrapolated to apply to similar ecosystems. Thus, an ecologist faced with the problem of assessing the environmental importance of a given stress impacting on a system can more readily arrive at an educated conclusion.

Comparisons of Metabolic[illegible] Four Ecosystems. Values are grams carbon/square meter/year

	Deciduous Forest	Coniferous Forest	Prairie	Tundra
1. Total photosynthesis	1,625	1,[illegible]	983	167
2. Plant respiration	960	[illegible]	613	159
3. Net production by plants (1 minus 2)	[illegible]	[illegible]	370	28
4. Respiration bacteria, fungi and animals	520	370	132	5
5. Net production by the ecosystems (3 minus 4)	160	230	238	23

Parallel studies recently brought to a point of meaningful synthesis in the Human Adaptability component of the IBP have been made in the higher Andes, treating the farming and herding Indians there as a problem in ecological energetics. In the cold, high altitudes, net production through farming is low, but grazing herds of llamas utilize untillable land. The skins and wool produced by herding are traded to lower altitudes for energy-rich foods high in carbohydrates. Nitrogen as the protein in hides and hair is transported downward from the high pastures, and energy-rich carbohydrates are carried upward in a countercurrent. These ongoing studies of the environment and man interpreted in the common terms of matter and energy can increase our understanding of how to use our resources.

GLOBAL ATMOSPHERIC RESEARCH PROGRAM*

Much of the 1973 Global Atmospheric Research Program (GARP) effort was channeled into planning and support for the GARP Atlantic Tropical Experiment (GATE) that is scheduled for the summer of 1974. A central scientific program plan was developed as well as plans for boundary layer, convection, oceanographic, radiation, and synoptic subprograms. These scientific plans will be converted into operational plans so all participants will know exactly what is to be done, when, and where.

Since the objective of GATE is to extend our knowledge of the meteorology of the equatorial belt so we can understand better the general circulation of the atmosphere, considerable effort has been devoted to improving tropical numerical models. One model developed at Florida State University by T. N. Krishnamurti and also at the National Center for Atmospheric Research (NCAR) is known as a limited area model. Such models have much greater horizontal resolution, down to 5/8 degree of latitude, than do general circulation models (GCM) that have a resolution of 5 degrees. The results indicate that these models will be quite useful in short-range forecasting.

To aid in using models that have a fine resolution, NCAR is reprogramming their GCM so it will run more efficiently on a fifth generation processor computer and can accept almost any horizontal and vertical resolution that is desired. Limits on this model will be due solely to computer core storage and speed.

University investigators are helping NCAR to improve their GCM for GARP purposes. Lewis Kaplan of the University of Chicago is making the infrared radiation calculations more realistic. Other improvements relating to the treatment of solar and atmospheric radiation, particularly in handling cloud effects, will be incorporated into the reprogramming effort.

As has been mentioned in earlier annual reports, NCAR has been delegated responsibility for work on Observing Systems Simulation Experiments (OSSE). The results of these experiments indicate that the combination of measurements from the basic observing system planned for the first GARP Global Experiment will yield a description of the Northern Hemisphere within the accuracy of the GARP requirements. Only in the tropical belt, 10 degrees S to 10 degrees N, is the wind field so poor as to demand a special observational system. In this area, a Carrier Balloon System will fly at 25 kms and release Omega dropsondes upon command. The wind profile will be measured by the falling sonde, the information received by satellite, transferred to a data acquisition station, and then further to NCAR for processing. A test of the system is scheduled for 1974.

The OSSE results also indicate that the basic observing system of radiosondes is insufficient for the Southern Hemisphere. Thus, other special observing systems such as the Global Horizontal Sounding Technique and the Tropical Wind, Energy Conversion and Reference Level Experiment are being developed and perfected through cooperative efforts between several nations, the National Aeronautics and Space Administration, NCAR, and university investigators.

INTERNATIONAL DECADE OF OCEAN EXPLORATION

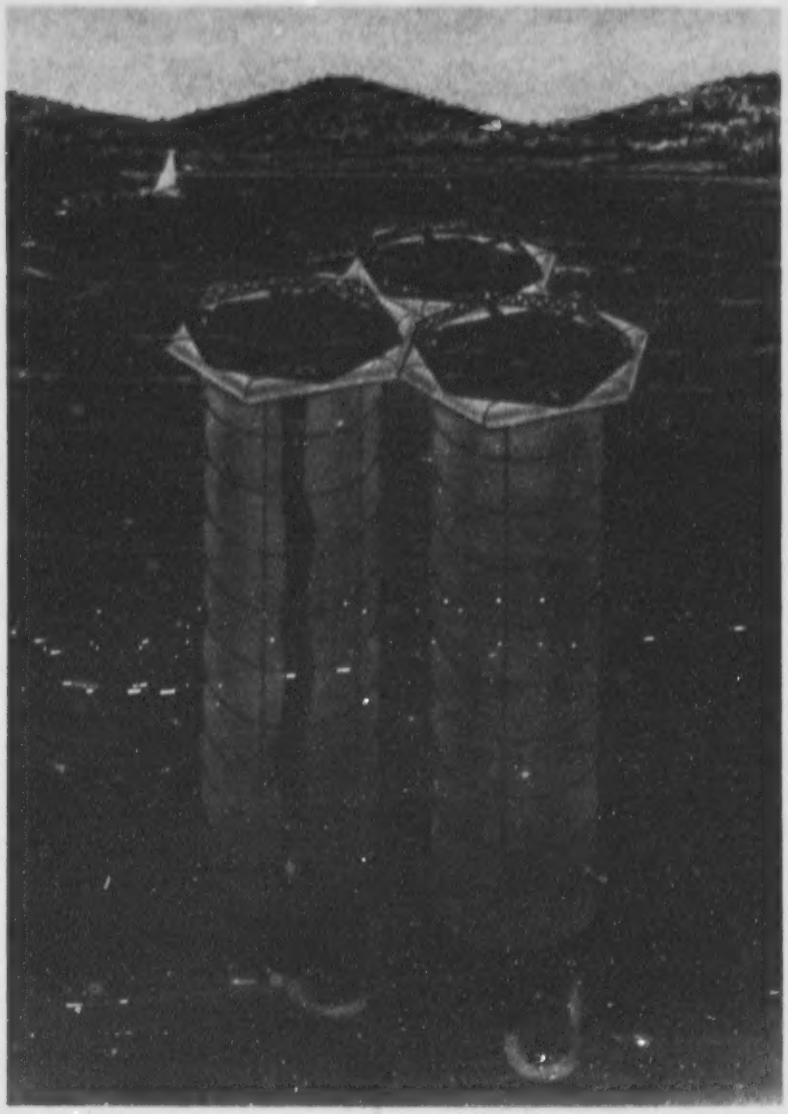
The Office for the International Decade of Ocean Exploration (IDOE) continued to work closely with the oceanographic community to design and implement projects in marine environmental quality, living resources, prediction of the state of the oceans, the oceans' impact on global

*Although administered by the Research Directorate, GARP is included here because of its identification as one of the Foundation's National and Special Research Programs.

weather, and the assessment of natural resources.

As part of its integrated research on marine pollution and geochemical processes, scientists in the Geochemical Ocean Sections Study (GEOSECS) are measuring ocean constituents at all depths along sections from the Arctic to the Antarctic in the Atlantic and Pacific Oceans.

Trace elements and radioisotopic data are used to establish geochemical baselines for quantitative studies of ocean mixing and for developing improved models of ocean circulation. The Atlantic transect was completed in April 1973. A new project in fiscal year 1973 was the Controlled Ecosystem Pollution Experiment (CEPEX), a study of the effects of chemical pollutants on marine organisms and communities. In this study, plastic cylinders suspended in the sea will provide controlled environments for examining the effects on marine organisms of persistent low-level exposure to pollutants.



These enclosed plastic cylinders (shown in an artist's concept) will enable experiments to be done on pollutants' effects on marine organisms and communities.

Improved understanding of the geological processes at work along the continental margins, the mid-oceanic ridges, island arcs, and abyssal plains is the objective of the Seabed Assessment Program. This knowledge will permit improved resource management and assist industry in planning for exploration of potential oil and mineral reserves.

The continental margin studies focus on the origin and evolution of the margins and the geophysical framework within which seabed resources have been formed.

The first part of the Southeastern Atlantic margin survey extended from Port Elizabeth, South Africa, to the Congo River and was completed in mid-1972. Several thick sedimentary deposits of the kind frequently associated with oil reservoirs were located off the Orange and Congo Rivers. The second part extended from the Congo River to Lisbon, Portugal, and was completed in mid-1973. Complementary surveys are being made along the Southeastern Atlantic margin. Work on the Nazca Plate, the East Pacific Rise, and the Peru-Chile Trench seeks to explore the relationship between crustal plate movement and the origin of metal-bearing deposits.

A review of data on deep-ocean manganese deposits, completed in 1973, identified major provinces of these materials on the seabed floor. Nodules rich in copper and nickel are abundant in the North Pacific, where further IDOE investigations may be made of the processes involved in the formation of ferromanganese deposits.

Research under the Environmental Forecasting Program will provide a basis for improved and extended forecasts of weather and

ocean circulation. As part of the Mid-Ocean Dynamics Experiment (MODE), which is a study of the nature and role of medium-size eddies in ocean circulation, a major field experiment was completed south of Bermuda between March and July 1973. It involved scientists from 12 U.S. and 3 foreign institutions.

The North Pacific Experiment (NORPAX), a long-term study of large-scale ocean-atmosphere interaction in the North Pacific, is moving toward a major field experiment in 1975. Historical data are being compiled and used to test hypotheses, numerical models are being developed, and instruments are being designed and tested.

The Climate: Long-Range Investigation, Mapping, and Prediction (CLIMAP) program is a study of changes in current patterns and water mass properties during the Quaternary period. Sediment cores are being analyzed and paleo-oceanographic maps constructed to determine natural fluctuations in climate and to evaluate man's impact on the global climate. Work proceeded on a global chart of sea-surface temperatures 17,000 years ago, and on the verification of solar effects on climate using core material dating back 700,000 years.

The physical and biological conditions associated with coastal upwelling are a main concern of the Coastal Upwelling Ecosystems Analysis project which seeks to understand the upwelling process so that the response of the system to change may be predicted from monitoring of a few biological, physical, or meterological variables. Physical and biological investigations will be conducted during the JOINT-I experiment, scheduled for early 1974 off the northwest African coast.

In 1973, the Intergovernmental Oceanographic Commission's Executive Council endorsed all of the major U.S. IDOE projects as part of the IOC's International Decade of Ocean Exploration. Foreign participation in U.S. IDOE programs rose to 34 countries during 1973.

POLAR PROGRAMS

The Tundra Biome project, aimed at modeling the tundra ecosystem and developing predictive models, entered its third field year, with emphasis on primary production, decomposition, nutrient cycling, and microclimate. Seventeen universities from 5 countries are involved in 46 different research and modeling projects.

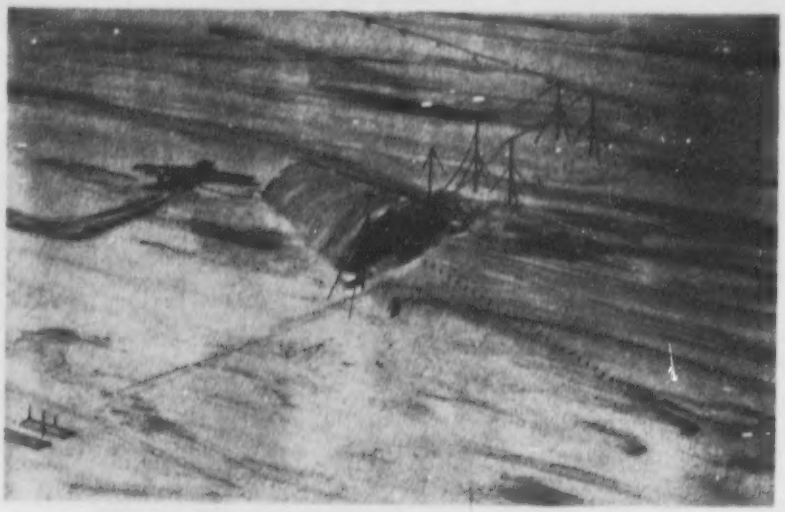
Plans are underway to initiate the Man-in-the-Arctic research effort, a long-range program developed in cooperation with other agencies and designed to gain a basic understanding of the forces of change in Alaska. Information derived from this project will be applied to the solution of critical problems of northern social and economic development.

No substantial field programs were conducted this year in the Arctic Ice Dynamics Joint Experiment (AIDJEX), but data buoys emplaced during the spring 1972 encampment on the sea ice north of Barrow, Alaska, continued to transmit information throughout the year via satellite. Substantial progress has been made in the development of realistic computer models of the Arctic Basin air-sea-ice dynamics. The main AIDJEX experiment is scheduled for 1975. Planning is moving ahead for joining AIDJEX with the larger, Soviet-originated Polar Experiment.

Shallow ice cores were obtained at two sites in Greenland for stable-isotope analysis to determine the air temperature at the time the snow was deposited. Intermediate-depth coring in 1974 and eventual deep drilling to bedrock below the ice sheet is expected to provide an exceptionally long climatic record.

In the Antarctic, Siple Station, in Ellsworth Land, was opened for year-round operation in January 1973. Four men are wintering over at the station studying the ionosphere and the magnetosphere. In May 1973, VLF signals were transmitted from the 21-kilometer-long dipole antenna to a conjugate-point receiving station in Quebec, which is linked by the same magnetic line of force or field line to the Antarctic station. Later, similar signals were received by the

SIPLE STATION (Artist Conception)



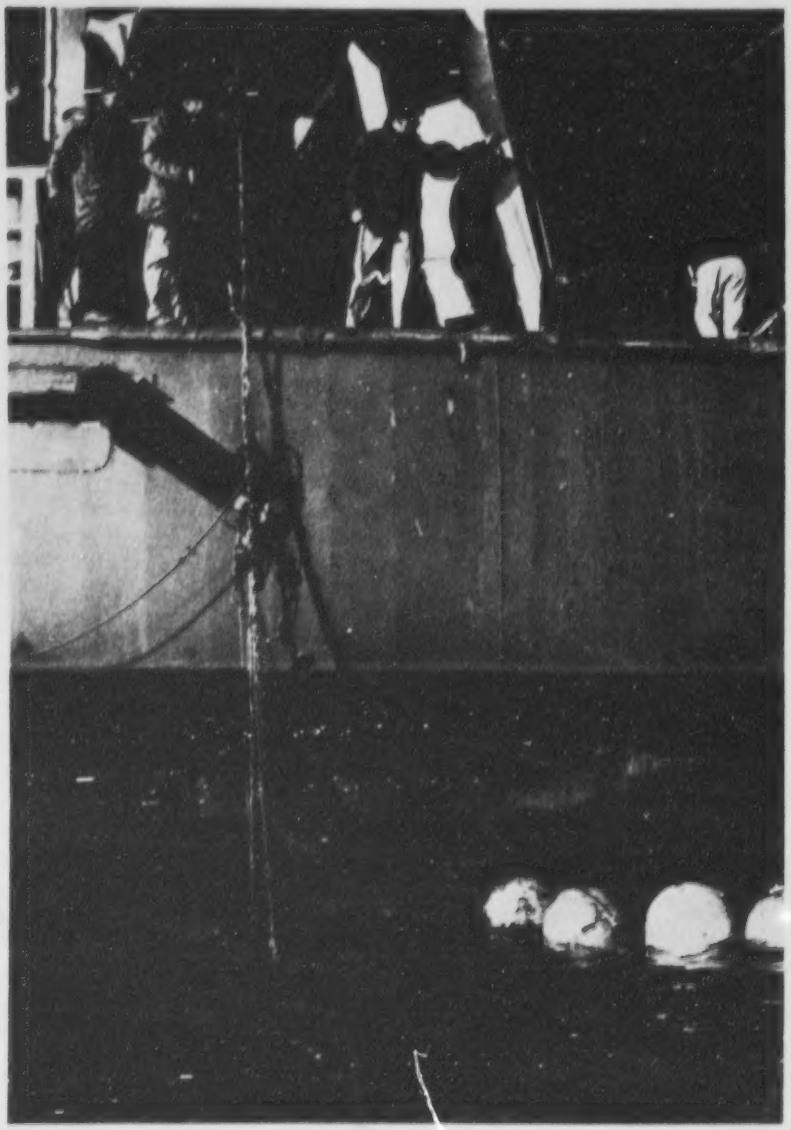
Four scientists studying the ionosphere and magnetosphere wintered over in Antarctica's Ellsworth Land at Siple Station, opened for year-round operation in January 1973.

Explorer 45 satellite (S^3) when it was 14 degrees north of the Equator. Data from these experiments will shed light on how particles and waves interact in space and how solar activity affects the distribution of charged particles.

The Coast Guard icebreaker *Glacier* penetrated the ice-filled Weddell Sea to collect hydrographic data and to make a third attempt to retrieve current meters emplaced at a depth of over 2,000 feet in 1968. This time, two of the four meters were recovered, yielding the first winter data from the area since Ernest Shackleton's ship *Endurance* was trapped in the ice in 1914-16.

The research ship *Eltanin* completed her 55th cruise for the U.S. Antarctic Research Program on December 29, 1972, after which she was called home and placed in ready reserve status.

Cores from two holes drilled about 630 feet into permafrost on Ross Island are expected to yield unique information on the geologic history of Antarctica. The cores contain volcanic materials and basalts interbedded with layers of ice, suggesting that the entire island has a complex volcanology that is interwoven with a long glacial and marine history. The cores complement ocean sediment cores taken by the *Glomar Challenger* in the Ross Sea in 1973 which indicate that the Antarctic ice sheet is over 20 million years old, far older than previously estimated.



One of four current meters, placed in the Antarctic's Weddell Sea in 1968, is retrieved and hoisted aboard the USCG icebreaker *Glacier*.

OCEANOGRAPHIC FACILITIES AND SUPPORT

NSF grants for oceanographic studies emanate from all directorates of the Foundation—reflecting the breadth and scope of the marine sciences—and are distributed among some 60 academic and private nonprofit research institutions. Of these 60 institutions, only 17 operate NSF-funded facilities, principally ships comprising the academic fleet. Support of the facilities required for the conduct of NSF-funded oceanographic research programs is provided through the Office for Oceanographic Facilities and Support (OFS).

To assure access to these facilities by NSF grantees from any institution, OFS works closely with the University National Oceanographic Laboratory System (UNOLS), a voluntary association of ship-operator institutions and representatives of the academic oceanographic community at large. UNOLS plays a major role in coordinating the shared use of the academic fleet and other specialized facilities. Highlights of UNOLS' accomplishments during its first year include: (1) community-wide ship scheduling meetings; (2)

distribution of annual and monthly composite academic fleet schedules; (3) development of an active staff office to provide year-round communications and system monitoring; and (4) completion of a first annual report with recommendations for improved and expanded oceanographic facilities support.

The Foundation is the primary source of Federal support for the operation of academic oceanographic facilities, contributing approximately 70 percent of the total annual operating cost in fiscal year 1973. For this reason, OFS performs a major coordinating function with other supporting agencies, principally the Office of Naval Research (ONR), in an attempt to assure equitable distribution of facility costs in proportion to utilization. NSF and ONR, the two principal supporting agencies, completed a joint study of the allocation of ship utilization costs that will lead to an improved system of post-cruise reporting. The new information system is being implemented through UNOLS.

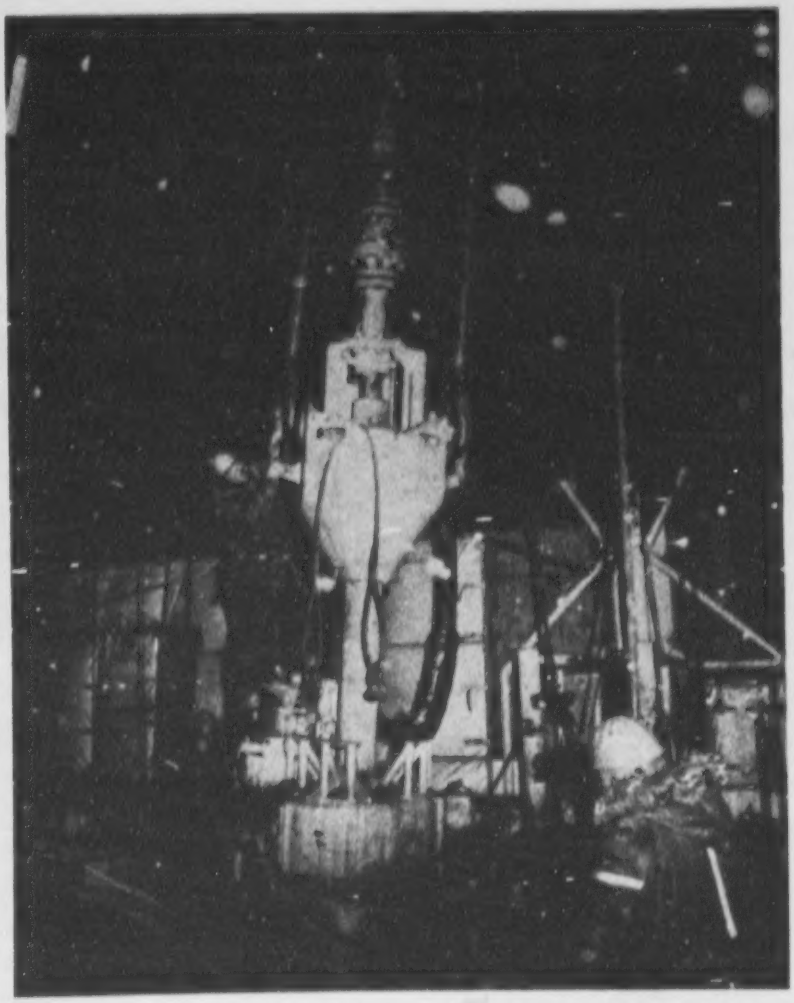
Other significant activities during fiscal year 1973 were: 15 grants were awarded for the support of about 125 seagoing technicians at 15 institutions; 20 awards were made for upgrading of shipboard and shore-based equipment; final plans were completed and bids received for construction of a permanent pier for the shore facility of the largest academic ship-operator institution; and R/V *Alpha Helix* and R/V *Eastward* were designated National Oceanographic Facilities. (National Oceanographic Facilities are special-purpose facilities such as one-of-a-kind platforms, ships with unique capabilities, or regional facilities. They are designated as such by UNOLS and the appropriate funding agency, with the objective of servicing the community broadly.)

With the planned reduction in the number of ships in fiscal year 1974, recent increases in the efficiency of the academic fleet become particularly significant: While the number of ships remained constant, the number of days logged at sea over the past 4 years increased from 6,851 in 1970 to 8,141 in 1973.

OCEAN SEDIMENT CORING PROGRAM

The main objective of the Ocean Sediment Coring Program (OSCP) is to obtain and study samples from the sea floor that will provide knowledge about the origins and dynamics of the oceanic basins and the continents. The samples are obtained by drilling and coring the sedimentary layers and upper portion of the underlying crystalline rocks from the drilling ship *Glomar Challenger*.

The main activity of the OSCP is the Deep Sea Drilling Project (DSDP), which is operated under contract with the Foundation by the University of California, with the Scripps Institution of Oceanography being delegated management responsibility. During the past 5 years of operations (August 1968 to August 1973), about 300 different sites have been drilled and cored in



The drilling ship *Glomar Challenger*, in Antarctic waters, continues an ocean sediment coring operation during a night snowstorm.

the oceanic basins and marginal seas. More than 50 sites were occupied during fiscal year 1973 in the Indian Ocean, in antarctic waters, and in the southwest Pacific Ocean.

During the first 6 months of fiscal year 1973, a general reconnaissance was carried out that established the gross limits of horizontal and vertical crustal movements within and around the Indian Ocean. The oldest oceanic rocks found in the Indian Ocean were determined to be about 140 million years old (Late Jurassic/Early Cretaceous in age). The eastern portion of the Indian basin was found to have originated in more southerly latitudes and to have been moving northward since the initiation of the Pacific-Antarctic Ridge spreading center in the Eocene (approximately 50 million years ago).

Glomar Challenger was placed in dry dock in August 1972, and modifications were made in preparation for operations in antarctic waters. Four successful months of drilling and coring in high latitudes south of Australia and New Zealand resulted in many significant findings. For example, evidence was found that glaciers have covered the Antarctic Continent for at least the last 20 million years. A major advance of the glacial-ice front climaxed about 5 million years ago, after which it retreated abruptly to about its present position. Subsequent fluctuations of the ice front have been relatively minor.

Near the end of fiscal year 1973, *Glomar Challenger* returned to the southwestern Pacific Ocean in order to seek answers to specific questions that were formulated after studying the previous drilling results from this area. Ages of origin were determined for several of the marginal basins between Australia and the Tonga-Kermadec Trench. Minor divergence in the direction of movement of the Australian plate and the Pacific plate from about 100 to 10 million years ago appears to have resulted in the sequential growth of these marginal basins. Subsequent convergence in the past 10 million years has produced the trenches and volcanically active arcs that characterize the area today.

International participation in the DSDP continued during fiscal year 1973. Of the total of 330 scientists who have participated on board *Glomar Challenger* during the 5 years of operations, 107 have been from 22 foreign countries. Institutions within the U.S.S.R. and the Federal Republic of Germany have been invited to join the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES) consortium that provides advice to Scripps Institution of Oceanography regarding the scientific aspects of the DSDP. Heretofore, JOIDES has been comprised of five of the leading oceanographic institutions in the United States.

SOLAR ECLIPSE SUPPORT

A total eclipse of the Sun, one of nature's most spectacular displays, occurred on June 30, 1973. The shadow of totality (the Moon's shadow) began at sunrise near the border of Guyana and Brazil, crossed the Atlantic Ocean, and entered the African Continent at Mauritania. The shadow then moved eastward over Mali, Algeria, Niger, Chad, the Central African Republic, and Sudan—across over 2,000 miles of desert. It then progressed across the semi-desert lands of Uganda, Kenya, and Somalia, where it moved out over the Indian Ocean and left the Earth at sunset south of the Seychelles Islands. Generally favorable viewing conditions at the sites and preliminary analysis of data by observers of the eclipse indicate that valuable scientific data have been obtained.

The Foundation supported 38 major experiments in Africa aimed at learning more about the Sun and the effects of the total eclipse on the Earth's environment. Observations were made at Loiyengalani in Kenya, Chinguetti in Mauritania, and five smaller sites in Africa, in which 106 Foundation-supported scientists and technicians from 25 universities, 3 National Centers, and 1 industrial

Scientists in Kenya prepare their instruments for the June 30, 1973, solar eclipse.

organization took part. Other observations were made from aircraft and aboard Texas A&M's ship, *Texas Clipper*. Logistic support for U.S. scientists was provided through the National Center for Atmospheric Research.

NSF-supported scientists aboard the Los Alamos Scientific Laboratories' jet aircraft were able to stretch totality to 12 minutes (vs. 7 minutes on the ground) by flying down the path of the eclipsed Sun. The Foundation also supported several scientists who were aboard the French Concorde which achieved approximately 74 minutes of observations as it raced the Moon's shadow at supersonic speed.

The Foundation coordinated all U.S. efforts related to this eclipse, both nationally and internationally. Coordination of Federal efforts was accomplished through an interagency coordinating panel of representatives of Government agencies and scientific unions.

EXPERIMENTAL R&D INCENTIVES PROGRAM*

During the past year the Foundation launched a new program, the Experimental R&D Incentives Program, to test potential Federal incentives and the mechanisms to apply them, that could lower or eliminate barriers to innovation and technology transfer in the private and public sectors of the civilian economy.

The objectives of the program are (1) to obtain information experimentally on new means by which the Government can encourage the innovation of new technological products, processes, and services arising from research and development and shorten the time of technology transfer to private markets or to public service uses; and (2) encourage non-Federal investment in R&D activities. This program will seek to provide studies on the innovation process with real technologies and apply selected incentives for innovation through mechanisms that encourage new cooperative alignments of a variety of institutions to promote innovation.

A new organization, the Office of Experimental R&D Incentives, reporting to the Deputy Director, NSF, was established. Over 600 proposals were received and reviewed. Some 78 grant and contract awards, amounting to over $11.5 million, were made by this program from fiscal year 1973 funds. The awards were divided among planning, support, and background studies ($2.24 million), project experiment design and definition awards ($1.25 million), and exploratory test experiments ($8.0 million). In the first year of operation, 57 percent of the award obligations were made to private sector areas ($6.5 million) and 43 percent ($5.0 million) to public sector areas of interest.

Program activities for the year in the two sector offices and in the staff office for experiment design, program evaluation, and control are summarized in the following sections.

Private Sector

Approximately 500 unsolicited proposals were received in this area during the year from universities, industry, and nonprofit research institutes. Several background study contracts and three major experimental efforts were awarded.

• **Federal Laboratory Validation Experiment**—The incentive is the use of either Federal or other qualified private laboratories to perform validation testing of technological innovations of public interest.

Two awards were made to test innovations in water purification and waste water treatment systems.

• **University/Industry Cooperative R&D Programs**—Drawing on the previous extensive experience of both the Department of Defense university/industry coupling programs and the Pennsylvania Science and Engineering Foundation, an experiment was designed to test the incentive of Federal cost-sharing in a University/Industry Cooperative R&D Program. Federal cost-sharing of such cooperative projects will last up to a maximum of 5 years, after an experiment definition phase during which firm financial commitments are obtained from industry for mutually agreeable research programs. One award for a 5-year experiment was made to North Carolina State University for a cooperative R&D program with the furniture industry.

• **Innovation Centers at Universities**—A study of ten major technological innovations, entitled *Science, Technology, and Innovation*, by Battelle Institute, funded by NSF, recommended that perhaps the best way to bring about technological innovation is to find—if one can—a technical entrepreneur. This finding reinforced earlier recommendations: the education of technical entrepreneurs in the report of the 1965 Woods Hole Conference and the 1967 Department of Commerce report on *Technological Innovation, Its Environment and Management*. Based on such findings and recommendations, three experimental innovation centers were organized and funded. These are combined Engineering-Business School efforts at three universities to test the effectiveness of a laboratory-based, project oriented, clinical type educational experience in encouraging careers in technological entrepreneurship, and thereby stimulating technological innovation. Three experiments have been initiated with the University of Oregon, Carnegie-Mellon University, and MIT for a 5-year duration.

Public Sector

The mission of the Public Sector Office of the R&D Incentives Pro-

* Although the Office of Experimental R&D Incentives reports to the Office of the Director of the Foundation, it is included here because of its identification as one of the Foundation's National and Special Research Programs.

gram is essentially to conduct experiments to identify the dimensions of the Federal partnership role in assisting State and local governments in converting research and development to productive use and in stimulating greater non-Federal investment in research and development to meet State and local government needs.

In line with the concepts of new federalism, the Public Sector Program is oriented towards the needs of the State and local users of research and development. Experiments, therefore, must provide answers that are relevant to State and local operating officials—"technology-pull" rather than the "technology-push" approach is being emphasized. By coupling State and local governments with universities, industry, Federal labs, and other R&D centers in the experiments, it is hoped that close working relations between the supplier of research and development and the users will bring about greater understanding of the State and local world on the one hand, and awareness of new technological opportunities on the other.

The experiments will provide information to Federal R&D planners to help determine the kinds of Federal support which can be useful to State and local decisionmakers in utilizing and stimulating research and development, where and how such support should be applied to produce optimal results, and how various elements of the R&D community can be most productive in the process.

During its first year, the staff established its objectives, developed ten studies as background for potential future experiments, and selected one major experiment. This major experiment, authorized by contract at the close of the year, will test whether local governments can improve their capability to define their problems and convert research and development effectively to their needs by participating in an experimental national system. The system emphasizes management by a user-controlled, nonprofit R&D corporation. The user-controlled, nonprofit will be responsible for organizing a group of universities, industries, Federal laboratories, and other R&D organizations to assist 27 cities and counties of various sizes, descriptions, and abilities through specially assigned technology agents who will be responsible to local chief executives.

The experiment is scheduled to run for 51 months and is budgeted at $4.2 million. It will test the effectiveness of both the system and its component parts (the agent, the user-controlled nonprofit, the various R&D institutions individually and as part of a team), help determine the points in the innovation process where local governments require support from outside sources, and evaluate the relative effects of distance on delivery of technology to the user.

Experimental Design and Evaluation

The Experimental Design and Evaluation (EDE) Staff is charged with three primary responsibilities:

1. Document the "state-of-the-art" understanding of the technological innovation process and establish a range of possible options which might be worthy of experimental consideration by the program.

2. Develop, upon the direction of the program offices within RDI, an experimental approach or conceptual design to test possible new Federal policies or options.

3. Evaluate the results of the experiments which are executed by the program offices within RDI during the lifetime of the program.

During the first year of the program major attention has been given to the first two responsibilities. Twenty-three contracts have been awarded to contractors to document and focus on the range of possible Federal actions which impact the innovation process and have potential for experimental investigation. Fifteen of these contracts have been completed within the past year and have provided the program important insights into the range of possible experiments for implementation in the coming year.

The EDE staff has supported the program offices in devising the conceptual designs of each of the first four experiments which were initiated in the first year. In the coming year EDE efforts will continue to focus on the study and design areas; however, as data become available from the first four experiments, attention will be directed to the analysis and interpretation of the data from these experiments.

NATIONAL R&D ASSESSMENT PROGRAM*

The National R&D Assessment Program is designed to achieve a fuller understanding of:

- Relationships between Government policy options and R&D/technological innovation
- Processes of technological innovation
- Socioeconomic effects of R&D/technological innovation (e.g., externalities, productivity, employment, income, foreign trade, and individual well-being)
- Existing data and information relating to R&D/technological innovation, and gaps in the data and information

The program is guided by the needs of Government policymakers for information and analysis which will help in the decisionmaking process affecting research and development and technological innovation. Studies of Government policy options, combined with a fuller under-

* Although the National R&D Assessment Program reports to the Office of the Director of the Foundation, it is included here because of its identification as one of the Foundation's National and Special Research Programs.

standing of the processes of technological innovation and of the net benefits to society from such innovation, attempt to provide a framework of knowledge within which decisionmakers may consider various policy options and their likely consequences.

Work under this program can be roughly categorized in three broad areas. The first area will examine past, present, and alternate future policies and practices of governments and assess the relationships between policy options and the processes of technological innovation. Emphasis will be placed on government policies manifested through expenditures, the tax system, and the legal framework. In addition, the experience of other industrialized nations in the area of science and technology policy will be studied to determine implications for U.S. policy options. The first studies in this area are to concentrate on a determination and evaluation of the state of knowledge. These studies will be followed in subsequent years by more in-depth studies to overcome uncertainties and fill gaps in information. In fiscal year 1973, work was undertaken on the following specific subjects.

- A state-of-knowledge review of the effect of patent and antitrust laws, regulations, and practices on innovation
- Effect of patent-antitrust interaction upon innovation
- A cross-national literature survey and analysis on economic regulation and technological innovation
- Government policies and technological innovation
- Reviews of work on an evaluation of foreign experiences in national support for science and technology

The second area in this program is to study the socioeconomic consequences of technological innovation with the aim of establishing methodologies and estimates to measure and analyze the effects of technological changes on socioeconomic activities. Specific studies started in fiscal year 1973 are:

- Studies of social and private returns from technological innovation
- A study to analyze the factors leading to technology transfer through licensing and foreign investment and their impact on the firm
- The impact of multinational firms on technology and trade flows
- Dynamics of international transfer of technology
- A state-of-knowledge study on factors affecting economic payoffs from technological innovation
- Effects of innovation on demand for and earnings of productive factors
- A survey of relations between market structure and innovation
- Technological change, product proliferation, and consumer decision processes
- Benefits and costs to individuals of increased variety of consumer goods
- Literature survey and assessment of adjustment mechanisms and forecasting techniques on technological change and manpower opportunities and displacement

The third area explores innovation for a better understanding of the processes and decisions involved and the screens and incentives that operate. An understanding of how the innovation process works is necessary to ascertain the points for Federal participation if policymakers feel that such participation is warranted. Included in this area are the processes of innovation that may pertain specifically to the public sector. In fiscal year 1973, work on the following specific subjects was started:

- Diffusion of technology in State mission-oriented agencies
- State of knowledge of understanding of the innovation process
- Case studies and modeling of the innovation process
- Field studies of technological innovation processes

NATIONAL RESEARCH CENTERS

In order to meet national needs for advanced research in astronomy and atmospheric sciences, the Foundation provides support for the development and operation of five National Research Centers. Each center makes available to qualified U.S. scientists specialized instrumentation facilities and operational support which are beyond the capabilities of single educational or research institutions. The centers maintain scientific staffs which conduct research programs, provide scientific expertise in support of the research programs of visiting scientists, and develop advanced instrumentation.

Table 4
National Research Centers
Fiscal Years 1971, 1972, and 1973

	Fiscal year 1971			Fiscal year 1972			Fiscal year 1973		
	Capital obligations	Research operations and support services	Total	Capital obligations	Research operations and support services	Total	Capital obligations	Research operations and support services	Total
National Astronomy and Ionosphere Center	$3,755,000	$2,343,600	$6,098,600	$1,000,000	$2,787,500	$4,687,500	$399,000	$2,851,000	$3,250,000
Kitt Peak National Observatory	127,000	7,072,600	7,199,600	456,000	7,243,881	7,699,881	70,000	7,780,000	7,850,000
Cerro Tololo Inter-American Observatory	313,000	1,967,000	2,280,000	385,000	2,115,000	2,500,000	216,000	2,484,000	2,700,000
National Radio Astronomy Observatory	—0—	6,837,400	6,837,400	80,000	6,589,900	6,669,900	1,000,000	6,950,000	9,950,000
National Center for Atmospheric Research	270,990	14,224,664	14,495,604	1,000,000	17,177,416	18,177,416	—0—	16,000,000	16,000,000
Total	$4,465,990	$32,445,214	$36,911,204	$3,021,000	$35,913,697	$39,734,697	$3,685,000	$36,065,000	$39,750,000

NATIONAL ASTRONOMY AND IONOSPHERE CENTER

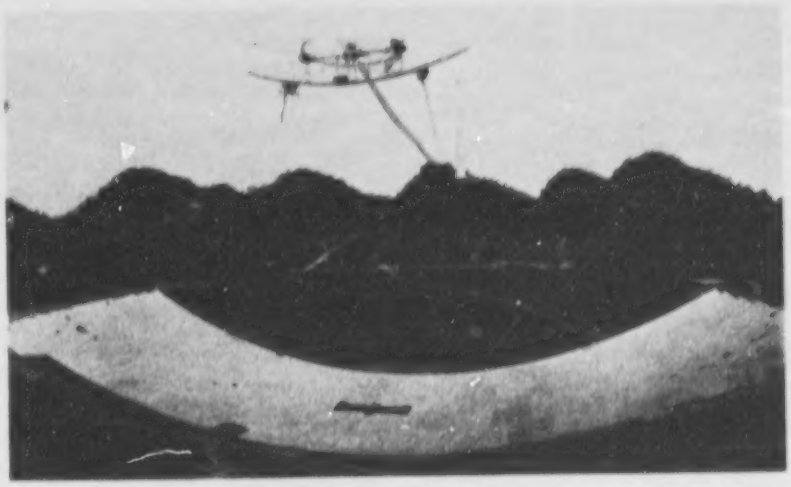
The National Astronomy and Ionosphere Center (NAIC) is operated by Cornell University under contract with the National Science Foundation. The center's principal observing instrument, a 1,000-foot-diameter, fixed spherical reflector, is located about 12 miles south of the city of Arecibo, Puerto Rico. Due to its capability of functioning actively as a radar telescope or passively as a radio telescope, the Arecibo instrument offers the scientific community unique research opportunities in astronomy and ionospheric physics.

A general upgrading of the 19.8-acre reflector surface to enable operations at higher frequencies is in progress. The present 1/2-inch wire mesh surface is being replaced with a precision surface of 38,778 adjustable aluminum panels. Installation of the panels is scheduled for completion in January 1974, and the final adjusting, or "tuning," of the new surface during the following months.

With support from the National Aeronautics and Space Administration, the observatory will be provided with an S-band radar [operating on a frequency of 2.4 GHz (gigahertz—billion cycles per second)] that will enhance planetary radar research capabilities when used jointly with the upgraded reflector. The S-band program provides for fabrication of a 450 kilowatts radar transmitter and certain stabilizing modifications of the suspended support platform to provide a high degree of beam-pointing accuracy. Completion of the S-band transmitter installation is scheduled for the first half of fiscal year 1975.

NAIC's Zeman Road Feed Laboratory fabricated a new 611 MHz (megahertz—million cycles per second) multibeam feed array for the Arecibo telescope. This array can place 10 independent antenna beams on the sky simultaneously and allows great expanses of the sky overhead to be observed quickly. After processing through NAIC's CDC 3300 computer, data from the multibeam system are used to produce very reliable maps of radio sources.

During the fiscal year, 27 visitors from 19 institutions utilized the observatory's research facilities. It is expected that the number of visiting scientists will increase when the major telescope upgrading programs are completed. The number of visitors from the general public has increased to 20,000 per year.



The resurfacing of NAIC's 1,000-foot radio telescope, shown with about one-third of the new reflector panels in place, will permit operation at higher frequencies. (Photo by NAIC)

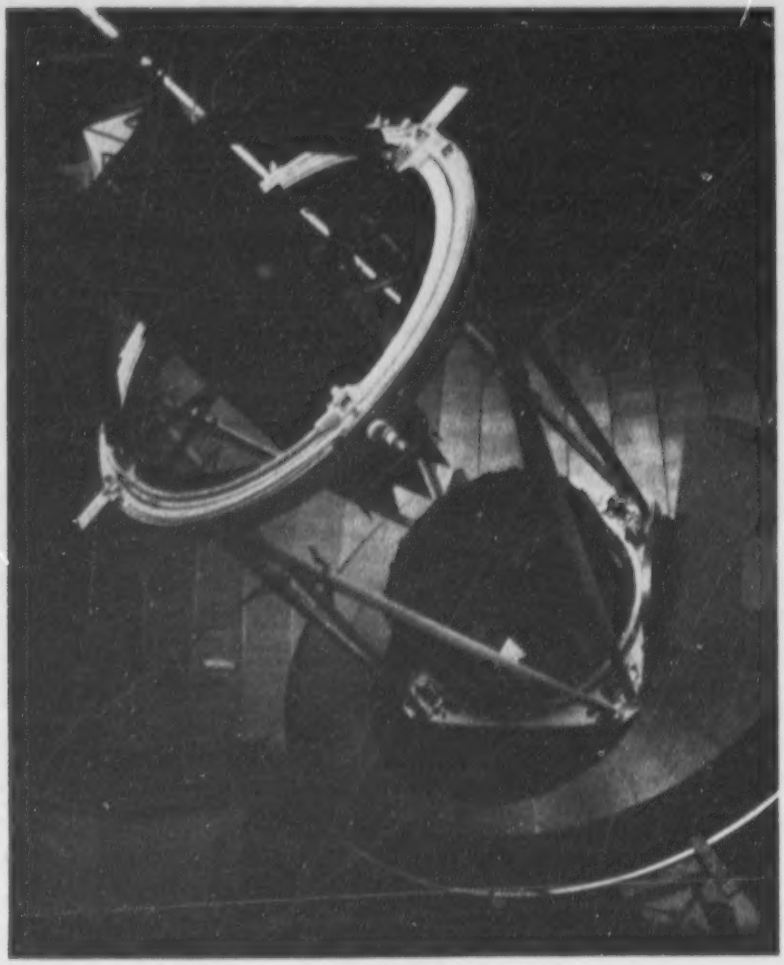
KITT PEAK NATIONAL OBSERVATORY

The Kitt Peak National Observatory (KPNO) is operated under a National Science Foundation contract with the Association of Universities for Research in Astronomy. The mission of the observatory is to provide advanced research facilities for the Nation's astronomers.

On June 20, 1973, the world's second-largest optical telescope, the 158-inch Nicholas U. Mayall reflector, was dedicated. This major instrument represents the results of 15 years of planning, design, and construction. The 15-ton fused quartz mirror, literally floating on air by resting directly on 36 supporting air pads, does not sag by more than one or two-millionths of an inch.

The 158-inch telescope joins six other stellar telescopes having apertures of 85, 50, (2) 36, and (2) 16 inches, the 60-inch McMath Solar telescope, and the newly constructed Solar Vacuum Telescope and Magnetograph. The latter instrument was designed to provide detailed, high-resolution magnetic maps of the solar disk. It will be used to provide ground-based data in support of the Skylab solar experiments.

During fiscal year 1973, the facilities at Kitt Peak were used by 236 astronomers, representing 64 U.S. and 14 foreign institutions. The observing time at KPNO is scheduled on a 60:40 ratio of visitor/staff time. During the past year, 66 percent of the actual observing hours were used by visitors on the 84-inch and 50-inch telescopes. Public visitors to Kitt Peak during the year numbered more than 57,000. An all-time record for monthly attendance was set in April 1973, when 8,974 visitors toured the facilities.



KPNO's 4-meter Mayall reflector, the world's second-largest optical telescope, was dedicated in June 1973. Among its unique features is the fast focal ratio of f/2.7 at the primary focus and a field of good definition nearly a degree in diameter.

CERRO TOLOLO INTER-AMERICAN OBSERVATORY

The Cerro Tololo Inter-American Observatory (CTIO) is operated under a National Science Foundation contract with the Association of Universities for Research in Astronomy. The mission of the observatory is to provide the scientific community with ground-based telescopes and research facilities for observing astronomical objects in the southern skies. Studies during the past year focused on the Magellanic Clouds, the southern Milky Way, and the galactic halo near the south galactic pole.

The low thermal expansion mirror blank for the CTIO 158-inch telescope passed from the grinding to the polishing and figuring stages at the Kitt Peak optical shops in Tucson, Ariz. The telescope is scheduled for completion in fiscal year 1975. The completed building for this new telescope, now housing the Cero Tololo electronics shops, is being prepared for the erection of the telescope mount assembly, which was shipped to CTIO from the United States in June 1973.

The central data acquisition and processing system was expanded to include the 60-inch, the 36-inch, and one 16-inch telescope. Auxiliary data are collected by interferometers, photometers, image tubes, and a spectral scanner.

During fiscal year 1973, 84 visitors, representing 43 U.S. and 8 foreign institutions, carried out observational programs at CTIO.

NATIONAL RADIO ASTRONOMY OBSERVATORY

The National Radio Astronomy Observatory (NRAO) is operated and managed by Associated Universities, Inc., under contract to the Foundation. Headquarters activities are centered in Charlottesville, Va., and the principal observing site is at Green Bank, W. Va. There is also an observing facility at Kitt Peak National Observatory in Arizona, and a site for the Very Large Array (VLA) radio telescope facility has been selected near Socorro, N. Mex.

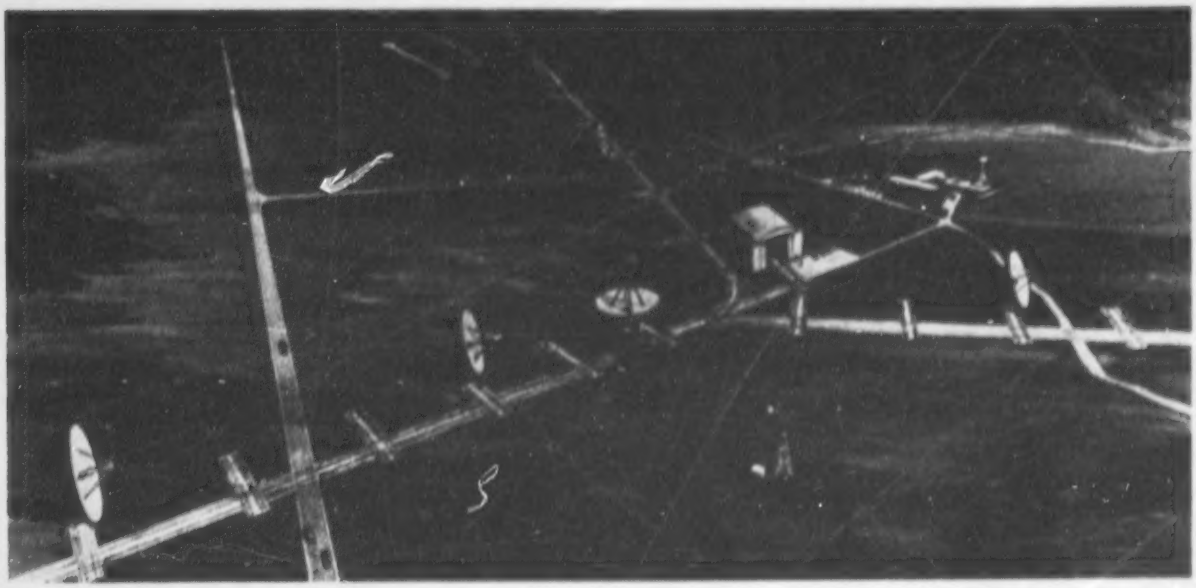
Three major radio telescope systems are in operation at Green Bank: a 300-foot-diameter meridian transit telescope, a 140-foot-diameter fully steerable telescope, and an interferometer. The Kitt Peak instrument is a 36-foot-diameter telescope having the pointing accuracy and precision surface required for operation at millimeter wavelengths.

The portable 42-foot-diameter antenna used for remote operations with the three 85-foot antennas of the Green Bank interferometer has been replaced with a new 45-foot telescope. This remote-controlled and fully steerable telescope provides for long baseline operation of the interferometer at its shortest wavelength.

A new drive and control system has been installed on the 140-foot telescope to improve the rate at which observations can be made on that telescope. Six new special-purpose receivers were placed in operation during the year, including two 250 GHz receivers at the 36-foot telescope. A remote terminal was installed at Green Bank to enable observers to run their programs on the main Charlottesville IBM 360/50 computer.

NRAO is proceeding with the final design and engineering of the VLA, to be located on the Plains of San Augustin, 50 miles west of Socorro, N. Mex. VLA will consist of 27 antennas, each having a diameter of 82 feet and weighing 160 tons, that are movable along railroad tracks arranged in the shape of an equiangular "Y." As the fiscal year ended, the specifications and design studies for the antenna elements had been completed and proposals for building the antennas were being evaluated. The acquisition of the New Mexico site was nearing completion. An engineer-architect firm was at work on the designs required for site development, building construction, and track-laying.

PANORAMIC VIEW OF VERY LARGE ARRAY SITE—NEW MEXICO



Final design and engineering was begun in 1973 for the Very Large Array radio telescope—27 individual 82-foot-diameter antennas movable along railroad tracks in the shape of a Y—to be built near Socorro, N. Mex.

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

The National Center for Atmospheric Research (NCAR) plays a unique role in the Nation's atmospheric science effort by conducting, in cooperation with university scientists, large interdisciplinary research projects and by providing the facilities and instrumentation required to carry out such projects. NCAR is operated under NSF sponsorship by the University Corporation for Atmospheric Research, a nonprofit consortium of 37 United States and 2 Canadian universities.

During fiscal year 1973, NCAR research activities involved approximately 160 visiting scientists and graduate students. Facility support was provided to approximately 390 scientists from 170 institutions. Among the major activities are portions of the Global Atmospheric Research Program (GARP), the National Hail Research Experiment (NHRE), and investigations of the structure of the solar corona.

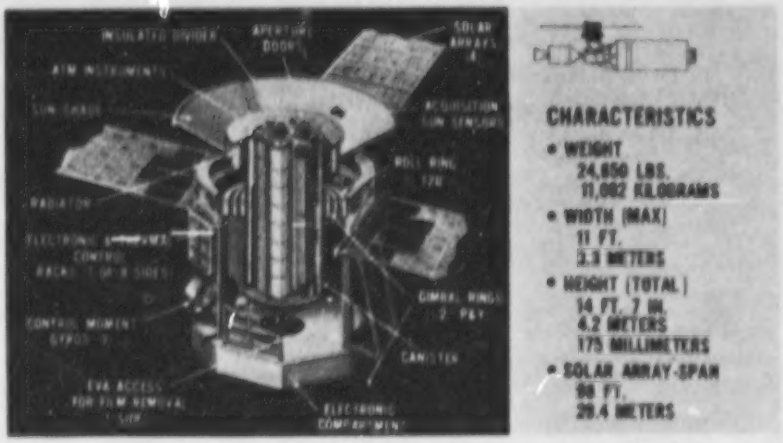
GARP is an international effort to determine the feasibility of forecasting weather for periods as long as 2 weeks. NCAR's participation in GARP is centered around the development of global, three-dimensional numerical models of the atmosphere. This work has reached a stage which permits the use of NCAR's models in experiments on weather prediction and climate problems, in which about 10 university groups are currently involved.

In addition, NCAR will participate in the GARP Atlantic Tropical Experiment (GATE), scheduled for fiscal year 1974, and in other GARP field programs, using a long-range aircraft capable of conducting complex experiments over the ocean. In fiscal year 1973, NCAR leased a Lockheed Electra which is now being modified and instrumented for this purpose. NCAR has also developed a wind-finding dropsonde capable of measuring atmospheric parameters critical to GATE, such as horizontal winds, pressure, temperature, and humidity.

The National Hail Research Experiment is a 5-year field research program with two goals: to gain an improved understanding of the dynamics and microphysics of hailstorms and to investigate cloud seeding as a tool to reduce hail damage. A major achievement was the development of an instrument to measure the liquid water distribution within a hailstorm cloud. An armored T-28 aircraft from the South Dakota School of Mines and Technology made more than 60 penetrations of clouds with the instrument, and obtained data indicating a fairly close correlation between strong updrafts and large accumulations of liquid water. In addition to the South Dakota group, key university participants in NHRE include the University of Chicago, the University of Oklahoma, the Illinois State Water Survey, the Desert Research Institute, the University of Wyoming, and Colorado State University.

In fiscal year 1973, the White Light Coronagraph (WLC), funded by NASA and designed by NCAR scientists, was installed on the Apollo Telescope Mount on board the Skylab. Synoptic observations of the solar corona from space will provide unprecedented time-consistent photographs and observations of coronal brightness and polarization. The WLC will also observe transient coronal events associated with coronal radio bursts and solar activity.

APOLLO TELESCOPE MOUNT (ATM)



NCAR scientists designed a white light coronograph which was installed on Skylab's Apollo Telescope Mount.

SCIENCE INFORMATION ACTIVITIES

In the past, Office of Science Information Service (OSIS) activities focused on improving access to the literature of various scientific disciplines. Beginning in fiscal year 1973, planning was initiated to expand information services to users in technological fields and to study the economics of information transfer. Support for improvements in information systems, a previous emphasis, continues, but with priority given to retrieval of quantitative data and development of compatibility and interconnections among Federal and private bibliographic retrieval systems. An expanded research program remains the basis of all OSIS activities. Added emphasis is being given to coordination of national and international information systems. Resources are being focused on these new priorities as offering the greatest potential for immediate improvements in the Nation's scientific communication capabilities.

Information Systems

The Information Systems Program concentrated on improving existing information retrieval systems. These systems provide ready access to the significant worldwide literature in the major fields of science and technology. Examples include the Chemical Abstracts Service (CAS), the Engineering Index, BioSciences Information Services (BIOSIS), the Geological Reference File, and the Current Physics Information System. All received Foundation support in fiscal year 1973 to accelerate completion of system improvements. A project initiated at BIOSIS to make the Biological Abstracts production system compatible with the Chemical Abstracts system is expected to lead to long-term cost savings to both organizations and to users.

Four user-oriented systems, located at the University of Georgia, Lehigh and Stanford Universities, and the Illinois Institute of Technology, became fully operational and self-supporting. The New England Board of Higher Education also received a grant to develop a Northeast Academic Science Information Center.

Data Systems

The Data Systems Program focused on facilitating access to the quantitative data derived from scientific research that are not now easily identified through literature-based systems. Emphasis is on retrieval of data with high potential for utilization in areas peripheral to the original, specific field in which the research was carried out.

To improve the accessibility of data reported in the scientific literature, projects were initiated to assure identification of data contents in the abstracts of individual papers published in journals. The data content portion will be made machine-readable and incorporated into the major abstracting and indexing systems. The program also supported a nationwide project for critical evaluation and compilation of nuclear data, and began development of a national data resources inventory.

Publications

The new thrust of the Publications Program is to seek innovations in the forms of publication and methods of distribution that will reduce costs and increase the value of publications to users. One approach is based on the design of alternative forms of an Editorial Processing Center through which small publishers can join forces to introduce cost-saving computer technology into their operations. Another project seeks to determine the characteristics of user demand for selectively distributed literature. Support was also provided for a number of publication projects and for the preparation of critical reviews and data compilations.

Research

During fiscal year 1973, several major efforts were begun including projects on resource sharing technology, means for retrieving specific information rather than citations only, user needs and information flow patterns, and a theoretical framework for information transfer.

In the area of user studies, a project was initiated at MIT to measure the impact of on-line interactive information services from the LEADER-MART system at Lehigh University on the informal communication networks which exist among scientists and engineers at the Environmental Protection Agency. Another project, at the Georgia Institute of Technology, seeks to link information systems technology with a system based on educational technology in order to meet the requirements of student users.

In the area of networking, a project at MIT will attempt to simplify user access to multiple interactive information systems by way of a higher-order common-use language as an alternative to standardizing the many existing systems. In another project, at Stanford University, an intensive comparative analysis is being conducted of 10 interactive search and retrieval systems in order to provide a basis for future interface development and/or standardization.

Finally, a study in the area of quality control of the literature was initiated at Johns Hopkins University. This project will attempt to

establish indicators of quality that might be used to reduce the amount of trivia entering the scientific and technical literature.

Foreign Science Information

The basic objective of this program is to facilitate communications between U.S. and foreign scientists. Utilizing U.S.-owned special foreign currencies in nine countries, approximately 35,000 pages of foreign books, journal articles, patents, and abstracts were translated and printed in fiscal year 1973 on behalf of the Foundation and 13 other Federal departments and agencies whose requirements in this area are coordinated and administered by NSF. The translations are made available to the general public through the National Technical Information Service.

Support was provided for U.S. representation and participation in the information activities of several major governmental and nongovernmental international organizations, including the United Nations Educational, Scientific, and Cultural Organization (UNESCO), the Organization for Economic Cooperation and Development (OECD), the International Council of Scientific Unions' Committees on Data for Science and Technology (ICSU/CODATA) and Abstracting Board (ICSU/AB), and the International Federation for Documentation (FID). The Foundation served as the focal point for expression of U.S. interests in UNESCO's UNISIST program, a worldwide voluntary effort to coordinate the interconnection of information systems and services

Under the U.S.-U.S.S.R. Agreement on Cooperation in Science and Technology, a Symposium on Scientific and Technical Information was held in Moscow in June 1973 to explore bilateral cooperative efforts of mutual benefit.

INTERNATIONAL COOPERATIVE SCIENTIFIC ACTIVITIES

The Foundation served as Executive Agency for 12 bilateral agreements, an increase of 3 over fiscal year 1972. It provided funds for the U.S. share of costs involved in 57 cooperative research projects, 30 joint seminars, and 8 exchanges of scientists conducted under these bilateral agreements. The following table summarizes the activities by country. In addition the Foundation continued to work with the Bulgarian and Czechoslovak Academies of Sciences to develop cooperative science programs with these organizations.

The National Academy of Sciences (NAS) received Foundation support for the exchange of scientific delegations with the People's Republic of China (PRC). The PRC sent five delegations to the United States and five U.S. delegations visited the PRC.

The exchange of scientists program, conducted by the NAS with the Academies of Sciences of the U.S.S.R., Bulgaria, Czechoslovakia, Hungary, Poland, Romania, and Yugoslavia, continued with NSF support. During the year 125 U.S. scientists visited the U.S.S.R. and six East European countries, and 109 foreign scientists came to the United States under this program. The countries, numbers of scientists, and man-months of visits are shown in the Exchange Program Table. In November 1972, the NAS and the Academy of Sciences of the U.S.S.R. agreed to consider a 50-percent increase in the level of exchanges, from 108 to 162 man-months each way annually, for the academic years 1974 and 1975. The agreed levels of exchanges (man-months) annually in each direction for the six East European countries are as follows: Bulgaria, 20; Czechoslovakia, 60; Hungary, 40; Poland, 50 (to be increased to 60 in the forthcoming year); Romania, 40; and Yugoslavia, 40.

The Foundation assumed a major role in the development of cooperative programs between U.S. scientists and their U.S.S.R. counterparts. The Director of NSF was appointed U.S. Co-Chairman of the Joint Commission for the U.S.-U.S.S.R. Agreement on Cooperation in the Fields of Science and Technology. The first meeting of the Joint Commission, held in Washington from March 19-21, 1973, approved for implementation 25 projects in six scientific areas: agriculture, chemical catalysis, application of computers to management, energy, microbiology, and water resources.

The Joint Commission also approved the establishment of a cooperative program in science policy, Soviet participation in the Deep Sea Drilling Project, and a joint Symposium on Scientific and Technical Information. Six additional areas for future cooperation were identified: forestry research and technology, standards and standardization, oceanography, transportation, special topics in physics, and electrometallurgy. The Foundation made 10 awards in support of U.S. scientific cooperation with Soviet scientists in chemical catalysis. Program definition and development in all approved areas continued throughout fiscal year 1973.

On September 27,1972, the United States and Israel agreed to establish a United States-Israel Binational Science Foundation. The Foundation, managed by a 10-man Board of Governors (5 appointed by each government), will promote and support cooperation in science and technology between the United States

International Cooperative Scientific Activities

Bilateral agreements	Number of awards by fields of science and activities: Mathematical & Physical Sciences	Biological Sciences	Engineering	Seminars	Exchange of Scientists
Argentina	1-physics				
Australia		1-rangeland environments		1	3 U.S. Visiting Scientists
Brazil	4-astronomy	1-biophysics			4 U.S. Visiting Scientists
Republic of China	3-geology	1-systematic botany 1-pathology		3	15 U.S. Visiting Scientists
Hungary	1-geology 1-chemistry	1-biophysics and biochemistry	1-civil and mechanical		
Romania	2-physics 1-chemistry 1-mathematics 1-meteorology		1-chemical 1-systems		8 U.S. Visiting Scientists 9 Romanian Visiting Scientists
Japan	5-physics 3-oceanography 3-geology 2-chemistry 1-aeronomy	1-biophysics 1-molecular 1-pathology 1-cellular 1-psychobiology 1-organismal 1-ecology	1-civil and mechanical 1-civil	24	10 U.S. Visiting Scientists
Mexico	1-physics 1-geology	1-molecular			
France	1-physics				12 U.S. Visiting Scientists 10 French Visiting Scientists
Italy	1-mathematics			1	
India					11 U.S. Visiting Scientists 14 Indian Visiting Scientists
Spain*	1-oceanography 1-environmental 1-geology	1-neurophysiology 1-molecular	1-civil	1	42 U.S. Visiting Scientists 29 Spanish Visiting Scientists

* Funds to support cooperative scientific activities under the U.S.-Spain Cooperative Science Program are provided by the Department of State.

Exchange of Scientists* Between the United States and the People's Republic of China (PRC)
Fiscal Year 1973

	Number of Persons	Period of Visit
U.S. Computer Group	6	July 10-28, 1972
U.S. National Medical Association	10	October 8-27, 1972
P.R.C. Medical Delegation	11	October 12-November 1, 1972
P.R.C. Scientific Delegation	10	November 20-December 13, 1972
P.R.C. Hydrotechnical (Water Resources) Study Group	10	April 21-June 11, 1973
P.R.C. Physics Study Group	13	May 20-June 24, 1973
U.S. Committee on Scholarly Communication with the P.R.C.	13	May 15-June 15, 1973
U.S. Medical Delegation	12	June 15-July 10, 1973
U.S. Physics Study Group	7	June 23-July 15, 1973
P.R.C. Insect Hormone Delegation	6	June 25-August 6, 1973

* Administered by the National Academy of Sciences.

United States-U.S.S.R. and East Europe Academy Exchange Program

Visits Each Way*

Country	U.S. Scientists	U.S. Man-Months	Foreign Scientists	Foreign Man-Months
U.S.S.R.	32	72	40	92
Bulgaria	11	18	5	18
Czechoslovakia	26	53	15	50
Hungary	16	35	17	50
Poland	13	42	13	62
Romania	15	39	13	33
Yugoslavia	12	50	6	11
Total	125	309	109	316

* For the period May 1, 1972, to April 30, 1973

and Israel. The NSF Director was elected Chairman of the Board.

International Organizations

The Foundation continued to support the NAS to enable it to exercise its membership in the International Council of Scientific Unions and to support participation of U.S. scientists in international scientific planning and program activities. The NAS, with funding from the Foundation, is also a member institution of the International Institute for Applied Systems Analysis. The charter for the institute was signed in London on October 4, 1972, and the institute was incorporated under Austrian law and located in Laxenburg, Austria. The representatives of the 13 member institutions, representing Bulgaria, Canada, Czechoslovakia, the Federal Republic of Germany, France, the German Democratic Republic, Hungary, Italy, Japan, Poland, the United Kingdom, the United States, and the Soviet Union, met several times during the year to plan the initial scientific program. A series of symposia was held in the summer of 1973 to bring experts together to define programs in such areas as water resources; energy; municipal, medical, computer, and ecological systems; and control of integrated industrial systems.

Special Foreign Currency Program for Scientific Research and Related Activities

The Foundation's Special Foreign Currency Program utilizes U.S.-owned excess currency in Egypt, India, Pakistan, Poland, Tunisia, and Yugoslavia to support joint research programs and seminars between U.S. scientists and those in each of these countries. Burma and Guinea are also excess currency countries; however, no cooperative research projects have been started in either country. In fiscal year 1973, the Foundation awarded 34 grants for cooperative research in these 6 countries, provided continued support for 9 projects, and made 38 travel awards to U.S. scientists to visit these countries to develop cooperative projects, attend meetings, or present lectures and seminars.

Under this program, the Foundation made available funds to the Polish Academy of Sciences to help support the construction of the Copernicus Astronomical Center in Warsaw in commemoration of the 500th anniversary of the birth of the famous astronomer. The new center, to be completed in 1975, will be used by astronomers of Poland, the United States, and other countries to conduct research in astronomy.

When the Department of the Treasury determined that U.S.-owned Yugoslav dinars would be depleted during fiscal year 1973, consultations were held between the United States and Yugoslavia which resulted in the establishment, on May 18, 1973, of a United States-Yugoslav Joint Board on Scientific and Technical Cooperation. The two governments contributed equally to a joint fund ($7.2 million equivalent of U.S.-owned dinars plus an equal amount from Yugoslavia) to prolong the availability of Yugoslav funds to finance cooperative research, and to promote other forms of scientific and technological cooperation.

RESEARCH MANAGEMENT IMPROVEMENT

The Research Management Improvement Program supports activities to improve the management of federally funded research in universities, colleges, and independent nonprofit research institutions. The major objective of the program is to enhance the effectiveness of such research through the development and implementation of improved institutional management procedures. A secondary objective is to identify those management problems at grantee institutions engendered by the administrative policies and practices of sponsoring Federal agencies and to seek solutions to these problems. The third objective is to disseminate information produced by this program.

Important Notice No. 44, dated August 21, 1972, which announced this new program, generated 157 requests totaling $16.0 million. They were received from 139 institutions of higher education, 4 State systems of higher education, 5 independent nonprofit research organizations, 5 established consortia of universities and colleges, and 5 other organizations.

Support totaling $992,385 was awarded for 12 of these projects. Besides dealing with problems of a general nature in research management, the projects are also directed to the special management problems created by: (1) multicampus research; (2) large interdisciplinary research projects; (3) research centers and institutes; (4) allocation of research resources; (5) project evaluation and coordination; (6) interaction in research activities with industry; and (7) requirements imposed by sponsoring Federal agencies.

Research Applications

Research Applications

The Research Applications Directorate completed during fiscal year 1973 the second year of operation of the RANN—Research Applied to National Needs—Program. This effort, together with the associated Intergovernmental Science Program, explores opportunities for industry, government and the university-based research community to undertake cooperative efforts to address major national problems. RANN's responsibility is to link basic knowledge and the application of knowledge by identifying opportunities, supporting research to elucidate these opportunities, proving some of the most promising concepts, and transferring the results of this effort to users. The users may be in the private sector of the economy, in the State and local governments, or in the departments and agencies of the Federal Government that have responsibilities for actions in given areas.

During fiscal year 1973, the RANN programs were organized in three major areas: Advanced Technology Applications, Environmental Systems and Resources, and Social Systems and Human Resources. Pioneering activities and technology assessments were carried out in a program of Exploratory Research and Problem Assessment. Linkage with users and user communities took place through a program of Intergovernmental Science and Research Utilization.

Total obligations in the RANN and Intergovernmental Science Programs grew from $54.85 million in fiscal year 1972 to $70.88 million in fiscal year 1973. With this level of funding, only a portion of the opportunities for research applied to national needs could be supported, and stringent criteria were applied for the selection of RANN areas of activity.

These criteria include the importance of the problem, the pay-off to be realized, the leverage of science and technology on the problem, the readiness of capable manpower to work on it, the capability of institutions, the need for Federal action, and an appropriate role of the National Science Foundation.

Another characteristic of RANN is its stress on the interdisciplinary approach to problem solving. Major RANN activities frequently require cooperative arrangements involving several or all of the RANN programs and staff offices. To provide for an integrated approach to interdisciplinary problems, the Research Applications Directorate established during the past year an Office of Systems Integration and Analysis. The major objective of this office is to analyze, develop, and structure integrated problem-oriented programs and projects. This office also assisted in the development of long-range (5 years) and short-range (1 year) plans for the Research Applications program and conducts broad system studies to identify those areas of research which can make the most significant contribution in solving a major national problem.

Activities were begun to develop more detailed, integrated plans in key program areas, such as solar energy, geothermal energy, and tunneling and excavation. Because of the dynamic nature of these and other program areas, continued reexamination and assessment of current plans were carried out. The Office of Systems Integration and Analysis also began the evaluation of productivity in selected industries—iron and steel, automotive, machine tool, electric machinery, food processing, and appliances—to identify areas in which research could produce significant improvements.

Also during the year a phased project planning system was established for carrying major projects and programs through the sequence from problem definition to proof-of-concept leading to transfer of

Table 5
Research Applications Obligations
Fiscal Years 1971, 1972 and 1973

(Millions of dollars)

	Fiscal Year 1971		Fiscal Year 1972		Fiscal Year 1973	
	Number	Amount	Number	Amount	Number	Amount
Research Applied to National Needs	213	$33 95	338	$53 77	616	$69 88
Advanced Technology Applications	122	14 65	163	18 35	262	28 94
Environmental Systems and Resources	48	9 75	98	19 45	148	27 50
Social Systems and Human Resources	15	7 10	25	11 28	122	13 35
Exploratory Research and Problem Assessment	28	2 95	52	4 69	84	5 09
Intergovernmental Science Programs	28	80	43	1 08	54	1 00
Total	241	$34 75	381	$54 85	670	$70 88

responsibility to users. To administer this system, RANN established a Public Technology Projects Office to manage projects from the establishment of requirements to the transfer of results to the appropriate public entity or the private sector. There are three phases in the system, as follows:

- Phase Zero—Detailed problem definition and requirements specification
- Phase One-Critical subsystem technology testing and preliminary design of the systems level experiment
- Phase Two-Systems level proof-of-concept test program leading to demonstration of concept feasibility

Specific activities in this area have been focused on moving two elements of the NSF terrestrial solar energy program into formal project efforts. First priority has been given to stimulating industrial interest and participation in solar heating and cooling systems for buildings. A request for proposals was issued in May 1973 for a Phase Zero requirements definition analysis. Work progressed toward the support of comparable efforts aimed at the utilization of solar energy for air conditioning.

ADVANCED TECHNOLOGY APPLICATIONS

In 1973 Advanced Technology Applications activity continued to emphasize the development and application of new technology that can contribute to the solution of national problems. The areas of energy, excavation technology, fire research, industrial processing, earthquake engineering, and instrumentation technology were among those to receive major support.

Energy

Growing concern over the Nation's energy situation highlighted the need for increased research in energy systems, resources, and technologies.

In January 1973 the Oak Ridge National Laboratory (ORNL) began publication of NSF-RANN Energy Abstracts, a monthly abstract journal of energy research. This survey of current energy research in the United States, carried out by ORNL, is intended to be useful to researchers and policy officials.

In February 1973 NSF supported the first formal conference on energy demand, energy use, conservation, and institutional problems associated with energy use. Over 700 persons attended the conference, at which 60 papers were presented. A selection of the papers is being published by the MIT Press.

Research was supported to develop and apply analytical techniques for examining energy policies and policy options. An econometric model of the natural gas industry was developed at MIT to examine the effect of alternative Federal policies on the demand for and supply of natural gas. Some preliminary results, dealing with the effects of deregulation, were presented to the Federal Power Commission and to the Domestic Council. An interfuel competition model was also developed at MIT to quantify the substitution between fuels resulting from changes in policy variables or from adoption of new technologies.

Energy conservation research was directed toward identifying and evaluating measures to reduce energy use in the residential, commercial, industrial, and transportation sectors. Studies at ORNL focused on savings obtainable from improved insulation and on options for improvement in the performance of air conditioners and heat pumps. Scenarios for slowing the growth of electricity demand in the residential sector in California to the year 2000 were developed by the Rand Corporation and are being used in the preparation of legislation by the California State Legislature.

Geothermal energy represents a potentially large source of power in the United States. Progress was made in developing physical and mathematical models of geothermal aquifers, and study teams on NSF projects are cooperating with the California Department of Water Resources to increase knowledge of the nature of the geothermal areas of the Imperial Valley. A team of university and industrial researchers began investigating a region of abnormally high heat flow near Marysville, Mont. Geophysical evidence to date suggest that this thermal anomaly could be a dry, hot rock formation, containing vast amounts of energy.

Consistent with the Nation's need to make more extensive use of its large coal resources, NSF supported research on advanced coal technology. This work, coordinated with the Office of Coal Research and the Bureau of Mines, provides fundamental underpinning for the development programs in these agencies. Coal gasification and liquefaction are two processes for expanding the use of coal in an environmentally acceptable way. Studies began on new methods of gasifying coal. Researchers at Pennsylvania State University in conjunction with Gulf Research and Development Corporation are seeking to relate coal characteristics to the behavior of coal in liquefaction processes.

NSF/RANN KILAUEA PROJECT AT KILAUEA VOLCANO, HAWAII

Nearing completion is a project in which Kilauea Volcano in Hawaii will be used as a geothermal field research laboratory. A major part of the program consists of drilling a test hole to intersect a ground water convection cell above the volcano's magma chamber.

Central station electrical power generating plants experience diurnal variation in power demand. One way of handling this variation is to convert off-peak electrical energy into chemical energy by means of high-performance storage batteries which can be tapped at peak periods. Electric vehicles will also require high-performance storage batteries. A project on the high-temperature lithium-sulfur battery spurred technical advances which enabled the demonstration of small, unsealed cells with performance characteristics in excess of 1,000 hours lifetime and 500 charge-discharge cycles. This is an important step toward the development of practical, high-capacity batteries. A second project is under way related to another advanced battery concept—the sodium/sulfur cell.

Interest in the prospects for solar energy continued to grow. Research was carried out in seven subareas of the Solar Energy Program during the last year: heating and cooling of buildings, solar thermal conversion, photovoltaic conversion, wind energy conversion, ocean thermal conversion, photosynthetic production of organic materials, and conversion of organic materials to clean fuels.

In the first of these subareas, the Foundation sought proposals for studies leading to the application of solar energy to water heating and the heating and cooling of buildings. These studies will constitute the first phase of work leading to proof-of-concept experiments in 1975.

In solar thermal conversion, research focused on the development of new optical coatings to trap solar energy at high temperatures, and on the analysis of systems and subsystems to identify the most attractive technologies for collecting, storing, and converting solar energy to electric energy. Research results verified that such systems are technically feasible. The University of Arizona reported that the performance of new selective optical coatings had improved by a factor of

WILSON SOLAR HEATED HOME TO BE BUILT IN WEST VIRGINIA

Estimates indicate that solar energy could provide at least half the energy needed for single-family dwellings in almost all regions of the United States. This drawing is of a solar home to be built in West Virginia.

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two in the last year over coatings previously used. In Minneapolis, a team consisting of researchers of the University of Minnesota, Honeywell Corporation, and Dynatherm Corporation began testing solar concentrators and a heat pipe for use in systems utilizing these optical coatings.

The use of solar cells, such as those developed for space to generate electricity, is a more formidable challenge since it involves reducing costs by a factor of 100 or more. In seeking for ways to reduce costs, one project has led to improved methods of depositing high-purity silicon on the metal base in the manufacturing process. Another has inaugurated the pilot production of cadmium sulfide/copper sulfide cells for laboratory and environmental testing. A third has shown some indications of possibilities for low cost and high efficiency in an approach that employs a Schottky barrier—that is, a contact between a metal and a semiconductor.

Additional solar energy conversion possibilities investigated included utilization of ocean thermal differences to generate electricity, the potential of wind energy to supply electricity, the production and collection of organic materials through photosynthesis, the conversion of wastes and other materials to fuels, and a mechanism for producing hydrogen from water through photosynthesis of green algae in conjunction with the bacterially produced enzyme hydrogenase.

Excavation Technology

Urbanization in the United States has resulted in severe pollution and congestion problems. Some of these problems could be reduced by utilizing underground space. Placing facilities underground offers attractive solutions to many problems, in addition to conserving valuable surface area.

The excavation requirements to meet the transferral needs vary widely, ranging from very small utility tunnels to large subsurface chambers. Research support is being provided by NSF to complement and supplement the work of several mission-oriented Federal agencies. Beginning with a modest research program of $720,000 in fiscal year 1972, research funding was expanded in fiscal year 1973 to approximately $3 million. This provided funds for significant research efforts to be initiated.

Research is being conducted in the areas of geologic fragmentation, geologic exploration, ground control and design, materials handling, and systems analysis and evaluation. One of the most promising approaches for tunneling is a rock-melting device called the Heat Subterrene, being developed at the Los Alamos Scientific Laboratory. The Subterrene has the potential of not only producing a smooth bore, but also of utilizing the geologic medium to produce an *in situ* structural liner. Two-inch-diameter holes have been drilled successfully to depths exceeding 100 feet. Conceptual designs for larger diameter Subterrenes have been made.

A versatile systems model to optimize tunneling procedures is being developed at MIT. This will be the first model capable of providing cost estimates for tunnel construction, determining the sensitivity of the various components of a tunneling

SUBTERRENE

Many potential applications exist for the Heat Subterrene, a new tunneling technology being developed at Los Alamos Scientific Laboratory.

system, and providing research priorities.

Full-scale linear cutting experiments on rock at the Colorado School of Mines have resulted in optimum ratios of cutter spacing to the depth of cut. These results will provide improved design for cutters on tunnel boring machines in the near future.

A novel method combining mechanical-thermal means of rock fragmentation has been developed at the University of Missouri-Rolla. The method consists of emplacing electric arcs at high temperatures into predrilled holes in a rock face, resulting in thermal fractures on three perpendicular planes. The rock can then be removed by mechanical means.

The Underground Construction Research Council has recently completed a report, "The Use of Underground Space to Achieve National Goals," which summarizes the requirements for use of the subsurface and recommends a large Federal research program in this area.

Earthquake Engineering

The Joint Federal Program in Building Practices for Disaster Mitigation entered its second phase during fiscal year 1973. The first phase resulted in a report outlining the best current practices employed in the architectural engineering and site design of buildings to resist earthquake damage. The second phase began with a major undertaking by the Nation's professional earthquake engineers to develop comprehensive seismic building code provisions. These provisions will be based on best current practice and on the extensive body of research results.

A research program conducted at Stanford University has examined costs associated with the seismic damage potential of mobile homes and light industrial buildings. Generally speaking, the resistance of a building to seismic damage may be increased by spending more for the first cost to construct the facility. However, incurring such costs is not thought to be a good business decision inasmuch as the expenditures would not be expected to pay for themselves. A question under investigation is: What is the proper mix between first costs and insurance costs to provide economic protection, presuming life safety is assured? Some expected first costs are found to be quite favorable. For an average mobile home located about 20 miles from a causative fault in California, the research concludes that provision for foundation attachment of the coach halves the expected damage. The expected first cost is $50, while the expected benefit from insurance cost savings is about twice this figure. However, current practice in the insurance industry does not provide for such adjustments, and the rates are currently at levels that make the provision of a foundation attachment uneconomic for this case, even though a small first cost is involved.

Fire Research

At the University of California, Berkeley, an interdisciplinary research project involving engineers and architects is directed to Fire Safety in Urban Housing. This and other fire research will provide better understanding of the important physical, chemical, and human factors which control the ignition and growth of fires in structures. Such understanding can be applied to improve materials and structures from a fire safety viewpoint and to provide scientific and engineering inputs to the process of formulating codes, standards, and design procedures.

At the University of Montana, under a research grant on the "Chemistry of Cellulosic Fires" directed by F. Shafizadeh, the mechanism for the breakdown of cellulosic materials to volatile and highly flammable tarry products and the composition of these materials have been identified. Fire chemistry research of this type has significant implications in understanding the principal factors involved in the spreading of fire and methods of controlling it.

Advanced Industrial Processing

The Foundation has provided support for research in enzyme technology and extractive metallurgy, both of which promise to yield great returns on investment and solutions to problems of national importance.

At MIT during fiscal year 1973, scientists succeeded with enzymes in synthesizing an antibiotic, Gramicidin S. The synthesis involved several enzymatic reactions and the consumption of cofactors, which are molecules that facilitate the transfer of energy of electrons. The MIT work brought the technology a step closer to the solution of the formidable scientific and engineering problems involved.

University-industry teams undertook efforts to study the production of fructose from glucose which is in turn derived from starch. The key issue being attacked in this work is the recycle and the stability of the enzyme, glucose isomerase. The work will soon reach the stage for the proof-of-concept experiments, which can lead to the production of sugar from cornstarch, which can potentially reduce this Nation's reliance on sugar import, currently at about $1 billion annually.

With NSF support, scientists at the University of Virginia built enzyme attached filters which can remove virus and bacteria from air or water. Laboratory results show a near complete removal of undesirable biological cells and application of such filters in environmental control is now being tested in hospitals, fisheries, and waste treatment plants.

Instrumentation Technology

Support for research on the application of new instrument techniques to the problems of diagnosis and treatment of disease was extended with the addition of five new projects. At the Oak Ridge National Laboratory comparative calcula-

tions are being made of the therapeutic value of different atomic particle types proposed for use in radiotherapy. More detailed calculations of the radiotherapeutic value of negative pions are being made, and results from this research will contribute directly to the instrumentation technology project at Stanford University for the development of a pion facility for cancer research. Researchers working on the pion facility, in collaboration with investigators at the University of California, San Francisco, have devised a new technique to image internal structures of the human body in three dimensions.

At Harvard University, the development of a technique to use proton activation analysis for calcium determination in human vertebra is being investigated as a measurement of clinical importance in the diagnosis and treatment of osteoporosis. Also of potential value to medicine is the research at the University of Nebraska-Lincoln concerned with the development of a better understanding of the effects of radiation in biological systems. At Stanford University a project to measure the acoustical discrimination of biological cells uses methods akin to those found in modern radar to distinguish different objects by means of their so-called acoustical signatures.

Mounting concern for environmental quality has led to a growing demand for instrumentation for research on trace contaminants and for monitoring environmental quality. At MIT tunable semiconductor lasers are being further developed for field tests of long-path infrared absorption for monitoring atmospheric pollutants. A project at Stanford Research Institute is designed to achieve range-resolved measurements of molecular atmospheric pollutants by observations of absorption in light backscattered from a laser beam.

ENVIRONMENTAL SYSTEMS AND RESOURCES

Competent and diverse scientific talents were successfully applied to environmental problems in projects supported in fiscal year 1973. The studies dealt with problems of weather modification, environmental aspects of trace contaminants, environmental instrumentation, coastal zone management, rural-urban development, impact of man on semiprimitive areas, land use allocation, and waste management strategies. Specific users of the research results, those who need the data, take part in the design and conduct of the investigations. Such involvement of beneficiaries in the scientific activities gives reality to objectives and practicality to the results.

Coastal Zone Management Research

The high intensity of land and resource use in coastal areas leads to conflicts among plans and actions. Some resolution of these problems was achieved by an interdisiplinary team at the University of Texas during 2 years of NSF support. The Texas Legislature and the Governor's Coastal Resources Management Program received the university's report containing usage criteria recommended for bays and estuaries on the gulf. Testing and perfecting the methodologies for determining usage criteria is continuing.

Coordinated interinstitutional studies of two major estuaries were aimed at a better understanding of the sources and effects of various forms of pollution. The Philadelphia Academy of Natural Sciences, Rutgers University, and the University of Delaware are studying domestic and industrial wastes in the Delaware Estuary. Similarly, the Smithsonian Institution, Johns Hopkins University, the University of Maryland, and the Virginia Institute of Marine Science are working together through a new nonprofit organization named the Chesapeake Research Consortium (CRC). A single problem area is the subject of the CRC study, i.e., waste treatment siting and outfall management on the Chesapeake Bay. The research is closely coordinated with several agencies, primarily the Environmental Protection Agency and the Corps of Engineers which has the responsibility of developing a management plan for the Chesapeake Bay area by 1976.

Land Use Allocation Research

Current legislative interest in land use and urban growth at State and Federal levels recognizes that conflicting demands for space and resources are intensifying. Short-term uses of land may conflict with long-range goals. Industrial needs often interfere with recreation, housing, and agricultural uses. While comprehensive planning and implementation are key to the pervasive societal issue, both the data base and methodology to evaluate interrelationships as well as tradeoffs are insufficient.

A workshop of national experts was convened by the Foundation to prepare an agenda of high priority research and a resulting book, *Environment: A New Focus for Land Use*

Planning, outlines research needs in the areas of environmental sciences, social and economic factors, demographic settlement patterns, and institutional requirements.

A research team at the University of Wisconsin completed a series of faculty seminars on land use problems in Wisconsin. Their analyses were published in eight volumes being used to formulate legislation for the State. Based on comprehensive assessment of present uses of land, its regulation, and responsible institutions, a series of recommendations were structured.

Several research projects concentrate on techniques and methods which can be used to aid the planning process and to increase the effectiveness for achieving land use goals. For example, research at Iowa State University is in progress on the growing impact of agricultural practices on water quality resulting from technological advances, economic development, and particular forms of public policy related to agriculture. A parallel award to the University of Houston supports research with the goal of developing measurements of the economic demands for water by selected sectors of the chemical industry.

Interim research results have assisted land use decisions in California. A major project at the University of California, Davis, is examining energy flow as a means for comparing different uses of land. This project has:

- Assisted the Pacific Gas and Electric Company in the development of a predictive model to forecast the effect of industrial and population growth on demand for natural gas.

- Provided a resource demand model to San Diego County, calculating (a) total electrical energy and natural gas consumption; (b) passenger vehicle air pollutant emissions; (c) quantity of land used by zoning classifications; (d) solid waste requirement for landfill and incineration; and (e) water demand.

Mercury as an Environmental Contaminant

Large segments of the human population are exposed to potentially hazardous materials spread widely through the environment as a result of industrial and agricultural processes. Recognition that a toxicological problem exists is often delayed because the amounts of material to which an individual is exposed are usually small, and any consequences are generally subtle and poorly defined.

Mercury has been known as a poison to industrial workers since ancient times, primarily as the metal or in simple inorganic form, but it has only been recently recognized as a lethal material in the form of salts of the alkyl compounds. The widespread occurrence of methylmercury, the most toxic form of mercury in man's food chain, underscores the continuing need to understand its effects. One of the major problems is the definition of "safe" levels.

The largest user of mercury is the electrical industry; in 1971, about 33 percent of the total mercury used in the Nation was used in the manufacture of batteries, lamps, power tubes, and other devices. Manufacture of batteries alone accounts for 25 percent of the Nation's use, and the mercury in mercury cells—about 73 percent of battery use—is economically recyclible. A program at Oak Ridge National Laboratory to recycle mercury in batteries has showed a savings of several dollars per pound of mercury, but only a small fraction of the mercury batteries used at the laboratory were actually collected.

Bioamplification and the association of mercury with organic matter are evident in Lake Powell, a recently created, relatively unpolluted reservoir on the Colorado River in Southern Utah. Formulation of an estimated mercury budget by an NSF-funded team suggests that the restriction of outflow in the impounded Colorado River leads to mercury accumulation, and that projected regional coal-fired power generation may produce amounts of mercury from coal to further augment natural weathering of native rock. Reported concentrations prior to the influence of power generation are (in mean parts per billion): 0.01 in lake water, 30 in bottom sediments, 34 in plant leaves, 145 in plant debris, 10 in crayfish, and 232 in fish muscle.

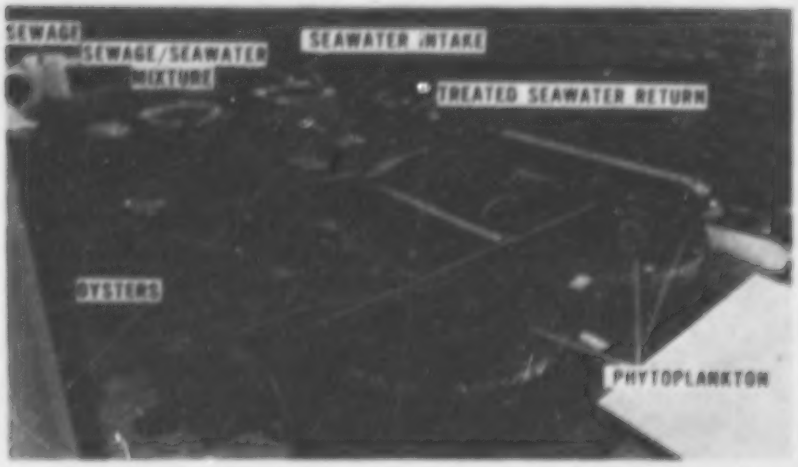
Many of the answers needed to define "safe" levels are sought from the study of humans exposed to inordinately high levels. The tragedy of the Iraq methylmercury poisoning outbreak afflicting 6,530 persons (with 460 deaths) provided an unusual opportunity to study the origins and fate of this toxic material as it was eaten on treated wheat almost directly in its commercial form. The NSF's support of a University of Rochester team initiated 8 months prior to the outbreak was primarily responsible for the analysis of health effects and responses. The body of information, with data collections and analysis still in progress, already constitutes the most complete clinical data to date on mercury poisoning, symptoms, and responses.

A multidisciplinary team has been established with members from various departments of Vanderbilt University, the Environmental Science and Engineering Corporation, and the Oak Ridge National Laboratory to assess the impact of mercury and other minerals on human health with particular emphasis on transfer from pregnant mothers to their unborn children. The four largest hospitals in Nashville, Tenn., have been sampled for human placentas and maternal and fetal cord blood. Also, mercury assays of brain, kidney, and liver tissues are made in nonsurviving fetuses.

Waste Management and Food Production

A combined tertiary sewage treatment-marine aquaculture system has been designed and successfully tested on a small, experimental

SEWAGE TREATMENT BY AQUACULTURE
Woods Hole, Mass.



An experimental sewage treatment system at Woods Hole Oceanographic Institution in Massachusetts uses effluent from secondary sewage treatment to grow marine algae, which remove objectionable constituents from the sewage. The algae, in turn, are removed and fed to oysters, resulting in further purified waste effluent and a commercial seafood crop.

scale at Woods Hole Oceanographic Institution in Massachusetts. In this system, the effluent from secondary sewage treatment, diluted with seawater, is used as a source of nutrients for the growth of unicellular marine algae. The algae, in turn, are fed to oysters or other shellfish. The algae remove the objectionable constituents from the secondary sewage effluent (ammonia, nitrate, phosphate, etc.) and the algae are removed by the oysters. The products are purified waste effluent, which will not support further algal growth (undesirable "algae blooms") in nature and a commercially valuable crop of seafood.

The above concept was successfully tested during fiscal year 1972 in the laboratory, under controlled conditions. During fiscal year 1973, the system was scaled-up, with individual components in the 500- to 1,000-gallon size range. It was operated out of doors under natural conditions, again with a high degree of success. It is projected that oysters obtained as "seeds" in early spring can be grown in this system to maturity in two summers under natural temperatures, perhaps in as little as 1 year in heated water.

The solid wastes produced by the shellfish do not affect the quality of the effluent from the system nor its effectiveness as a tertiary treatment process, but could present a solid waste problem of its own. These solid wastes, relatively high in organic content have been found to be a suitable food for certain deposit-feeding invertebrates, including worms and crustacea that may have commercial value in themselves (as human food or as bait for sports fishing) or that may serve as food for fin fishes, such as trout, salmon, flounder, etc. Thus, additional biological elements to the system are effective in reducing, if not eliminating, problems of waste production from the system itself and are capable of producing valuable, if small, secondary crops of commercially important species.

This tertiary sewage treatment-aquaculture system, as conceived and developed in these experimental models, is an ideal tool for studying marine food chain problems in general and the uptake, transfer, concentration, and loss of trace contaminants in such food chains in particular.

SOCIAL SYSTEMS AND HUMAN RESOURCES

The Division of Social Systems and Human Resources supports research intended to increase the effectiveness, efficiency, and equity of policies and programs dealing with municipal and human services at the Federal, State, and local levels.

Urban Public Safety Systems

Urban public safety systems—those that provide fire, police, and emergency medical services—are facing increased demands for services. State and municipal expenditures for such services have more than doubled since 1960 and totaled about $13 billion in 1969. With this increasing demand, it becomes imperative to evaluate the efficiency of present systems. Under an award to MIT, a research team

headed by Richard Larson is evaluating the effectiveness and efficiency of alternative resource allocation schemes, such as the comparative effectiveness of preventive versus standard police patrols and the use of independent on-site paramedical personnel versus physician consultation to paramedics via communication channels.

Telecommunication

In an attempt to develop the capabilities for policy-oriented research on telecommunications, grants were awarded for exploratory research useful to Federal, State, or local decisionmakers to produce alternative agenda for new telecommunications policy research, and for development of specific research proposals for submission to appropriate Federal, State, and local agencies.

One of the largest awards made in fiscal year 1973 was to the University of Miami for a controlled social experiment in the delivery of health care services to a prison population. The purpose of this project is to evaluate the potential for improving existing health care systems through the use of communication technology. Work was undertaken to investigate the acceptance by the medical profession of the use of telecommunications; the educational aspects of the system for paramedics; and the efficiency and cost-effectiveness of the system. Results of this study should have significant ramifications for the delivery of health care to different patient populations.

Evaluation of Policy-Related Literature

Over the past 25 years, a very large body of policy-related literature has developed. However, this body of research has not been evaluated comprehensively with respect to technical quality, utility for policymakers, and potential for codification and wider diffusion. These bodies of literature are often difficult to locate, evaluate, and use in decisionmaking. In the interest of providing a sound basis for research, awards were made in the areas of human resources and municipal systems, operations, and services for the evaluation of policy-related literature.

Awards were made under two competitive program announcements—in municipal systems, operations, and services, and in human resources.

Research on Natural Disasters

Under an award to the University of Colorado, a group of researchers led by Gilbert White and Eugene Haas is assessing information available on 15 natural hazards, their incidence, the social costs associated with these disasters, and alternative adjustment mechanisms including preventive strategies and post-impact countermeasures. This project staff will also identify the major lines of additional research required for public policy purposes.

Drs. Haas and White believe that much of the cost of property losses in disasters are due to an overreliance on one aspect of technology or another. For example, exclusive reliance on engineering prevents consideration of other methods of preventing or minimizing losses. The researchers contend that what is needed is a mixed strategy that includes adequate zoning regulations, building codes, warning systems, relief measures, and insurance—all specifically tailored for areas according to the type of natural hazard which threatens the area.

Preliminary results of the investigation suggest that more effective warning practices at the local level could reduce economic losses by 9 to 13 percent. Thus, the adoption of these techniques could result in substantial economic savings, in addition to avoiding loss of human lives and human suffering.

Decentralization of Municipal Decisionmaking and Service Delivery

Two of the most common problems facing the cities today are the effective delivery of services to the public and the lack of confidence the public has in their ability to influence government policies. In 1973 New York City set in motion a plan to decentralize local government by moving some of the government functions from City Hall to the neighborhood level.

A group of researchers at Columbia University's Bureau of Applied Social Research, led by Allen Barton, has been studying the city's decentralization experiment. The experiment involved eight major agencies: the Police Department; the Administration for Environmental Protection; Housing and Development; Human Resources; Health Services; Parks, Recreation, and Cultural Affairs; Transportation; and the Addiction Services Agency. The research includes study of satisfactions and dissatisfactions with neighborhood life and governmental services, the priorities that residents and leaders would establish for improvements in their communities, the extent to which citizens participate in efforts to improve living conditions in their neighborhood and in the city government and get results, and an administrative analysis of the bureaucratic dynamics of the decentralization experiment. The research team surveyed the residents and community leaders of the five areas in the decentralization study and three "control" areas to determine their perceptions of community needs and their ability to deal effectively with the government in obtaining services. This survey, conducted in fiscal year 1973, provided an assessment of the communities before major changes associated with decentralization occurred.

Planning New Communities

Implementation of the Urban Growth and New Community

Development Act of 1970 has greatly accelerated the planning and building of new communities in the United States. Public support of new community development is, in part, based on the belief that new communities provide social benefits which are rarely achieved in less planned new urban development.

The Center for Urban Affairs at the University of North Carolina is evaluating 36 communities—15 new communities, 15 less planned communities, and 6 special communities such as retirement communities. The objective is to answer such questions as whether the federally insured communities contribute more to the residents' quality of life than do other communities; how the Federal New Community Development Program influenced developer decisions regarding housing, neighborhood design, and community facilities; and how the Federal New Community Development Program can be applied most effectively to produce communities that improve the quality of life of their residents.

Preliminary analysis completed in the first year of the 2-1/2-year project suggests that the design of educational facilities in new towns needs much more attention. It indicates also that the socioeconomic mix required by Federal New Communities legislation can most effectively be achieved within neighborhoods rather than between neighborhoods, and that services are delivered more effectively by general units of government rather than by specially created units.

EXPLORATORY RESEARCH AND PROBLEM ASSESSMENT

As a pathfinder for the RANN program, the Office of Exploratory Research and Problem Assessment (ERPA) supports research that identifies emerging national needs and alternatives for responding to them through applied science and engineering. It undertakes policy-related systems-oriented assessments of significant problems of society, and supports exploratory research on some of them. The technology assessment activities of the Foundation are also centered here. There is a continuing effort to bring programs to a level of maturity at which they are suitable for transfer to a major RANN division or to another Federal agency; for example, the Industrial Automation Program shifted to the Division of Advanced Technology Applications at the end of the fiscal year. Representative accomplishments of the office are reviewed under the five major categories in which its projects fall.

Technology Assessment

This class of policy studies aims to identify, analyze, and evaluate the impacts of new or modified technologies on environmental, political, and other systems. It concerns particularly the second and higher order impacts and unintended consequences as well as options for dealing with them. Priorities and candidates for technology assessment are not only a continuing object of study for ERPA but a growing concern throughout the Federal agencies and Congress. Four projects, directed at defining priorities, have been completed:

- "A Survey of Federal Agencies' Priorities for Technology Assessment," by George Washington University;
- "Criteria and Candidates for Technology Assessment," by the Futures Group, Glastonbury, Conn.;
- "Technology Assessment Priorities Study," by International Research and Technology Corporation; and
- "Technology Assessment Needs at the State Level," by John Mock, Consultant.

Reports have been received and distributed on two major technology assessments. *A Technology Assessment of Offshore Oil Operations*, by the Science and Public Policy Program of the University of Oklahoma is significant not only for its potential impact on oil production policy but also as an example of how a university group can deal with a complex, multifaceted policy issue. The second report, *Ecological Resources and Socioeconomic Impacts of Advanced Automotive Propulsion Systems*, by Hittman Associates, Inc., is an example of a policy study produced by a profitmaking organization.

An assessment of the Impacts of No-Fault Insurance, conducted by the Institute for the Future, is an instructive example of assessment of a social technology conducted early enough potentially to inform the deliberation of the legislatures of the 50 States.

Technology and the Economy

As a keystone of the program in industrial automation, the University of Rochester, with a subcontract to a major machine-tool manufacturer, Gleason Works, is working to enhance the efficiency of discrete processes by further automating the programming of numerically con-

trolled machine tools while simultaneously improving practices in engineering graphics. A survey of current methods for parts programming has been completed.

ERPA research on consumer and the marketplace focusses on the areas of protection, education, information, and consumer behavior. A problem assessment of the field was begun in fiscal year 1973 by Survey Research Laboratory, University of Illinois.

Power and water, two essential needs of society, are subjects of ERPA research. The University of Notre Dame is studying decisionmaking in the power industry, in a program of exploratory research addressing the need to bring ethical and human value implications explicitly into the processes of technological decisionmaking. Antarctic iceberg resources to satisfy the growing global need for fresh water were the subject of a feasibility study undertaken by the Rand Corporation. It focused on the availability and acquisition costs of larger tabular icebergs of appropriate size, shape, and quality to be towed to coastal areas where they might be melted and their water used for a variety of purposes.

Human Needs

Data collected on the effects on black households and businesses of relocation for highway construction are being studied under an extensive program on minority group problems by a team of social scientists at Southern University, Baton Rouge, La. In San Francisco, a team of analysts from the Stanford Research Institute and a predominantly low-income Latino community group conducting a case study of community development and improvement, has assisted the community group with analyses of data and policy alternatives. Research into the barriers to diffusion of biomedical technology and into some of the associated policy problems is being investigated. The Human Interaction Research Institute, Los Angeles, Calif., is publishing a study on improved utilization of the best available treatment for chronic obstructive pulmonary disease. A researcher at the Ohio State Research Foundation is examining the impact and diffusion of innovations in kidney therapy, hemodialysis, and kidney transplantation.

Other Societal Problems

The largest element in this category deals with technology-related transnational policy questions. Some selected specific problem areas include global energy policy, international and environmental management problems, oceans policy, and international technology transfer.

NSF is also developing a data base on individual and institutional research experience and capability in other countries on problem areas of mutual interest. The intention is gradually to explore potential selected areas which might profit from research programs jointly sponsored by NSF and other countries.

INTERGOVERNMENTAL SCIENCE AND RESEARCH UTILIZATION

NSF's Office of Intergovernmental Science and Research Utilization (ISRU) has the dual mission of providing assistance to State and local governments to enable them to strengthen their research capabilities and of facilitating the utilization of RANN research in both the public and private sectors.

During fiscal year 1973 it became increasingly clear that in order for Federal, State, and local governments both to support and apply research and development in coping with domestic problems, new partnership arrangements must be forged—partnerships that allow State and local governments to participate in Federal R&D planning and Federal R&D agencies to share in the experience gained in follow-on implementation activities in State and local operations.

As a follow-on to the series of State-based R&D priorities conferences undertaken in previous fiscal years, an initial State government problem assessment project was begun with a former chairman of the National Science Board, Detlev Bronk, Chairman of the New York State Science and Technology Foundation, to develop an inventory of research and development needs with the objective of providing input to RANN priorities establishment and program planning. In addition, a grant was made in fiscal year 1973 to the Tahoe Regional Planning Agency for an experiment which would test a mechanism for coordinating the development and execution of a research program involving RANN research for the Tahoe Regional Planning Agency and would develop a Tahoe Basin Research Information System. A new approach to packaging and disseminating RANN and other research outputs was undertaken through a grant to Public Technology, Inc., for a Technology Information Exchange.

Continued emphasis was placed during the fiscal year upon activities designed to help State legislatures utilize research and development in legislative actions and to develop

better communication channels with the Nation's research community. NSF support for the California Assembly Science and Technology Advisory Council project, initiated in fiscal year 1970, began to phase out in this fiscal year. The activity demonstrated success to such an extent that it will be continued with State resources.

Both NSF and State support for the New York Assembly Scientific Staff has been continued after a first year of intensive activity in which the staff provided continuing input concerning the technological aspects of policy development and launched a significant collaborative study program between the States and colleges and universities and professional associations, thus permitting the interjection of science and technology into the decisionmaking process in a mode which has led to a high degree of legislative acceptance.

Among the new efforts commencing in the legislative area in fiscal year 1973 were grants to the National Legislative Conference (NLC), an affiliate of the Council of State Governments, and to the Legislative Research Commission of the State of Kentucky. The NLC has established a full-time professional staff capability with NSF support for the NLC Committee on Science and Technology to undertake studies relating to State energy policy, and building on previous ISRU grants.

Under the Lieutenant Governor, the executive branch of the State of California is continuing an active program to explore how State agencies can better use the resources of the State's colleges and universities, and the role of the State as a technical broker for local government. During the year, this activity was responsible for the dedication of State funds to the establishment of new and separate science and technology and energy offices which report directly to the Governor. The technology assessment activities of the Department of Planning and Economic Development in the State of Hawaii with both ISRU and State support have been influential in the development of the State's aquaculture program, as well as for the policy development relating to mining the extensive deep sea mineral deposits (particularly manganese nodules) existent in Hawaii's coastal waters.

The Technology Exchange Program of the Massachusetts Science and Technology Foundation represents an effort to assess the State's role in stimulating economic and industrial development. The activity is modeled after the British National Research and Development Corporation. The utility of the concept has now been tested out and proven successful.

Considerable attention was paid during fiscal year 1973 to cooperative Federal agency programs. A landmark survey of the research utilization practices of 17 Federal agencies was undertaken late in the year, and a policy study was prepared under the auspices of the Council of State Governments on the "Intergovernmental Uses of Federal R&D Centers and Laboratories."

Cooperative efforts with the Bureau of Census were undertaken to determine the feasibility of utilizing a self-instructional, computer-assisted teaching system for dual independent map encoding to be used by State, regional, and local government officials. In another interagency project, ISRU is working with the Agricultural Extension Service, the Environmental Protection Agency, the U.S. Corps of Engineers, and the States of Oklahoma, Tennessee, and Colorado in a pilot program for testing the use of the Extension Service in transferring environmental technology to State and local governments.

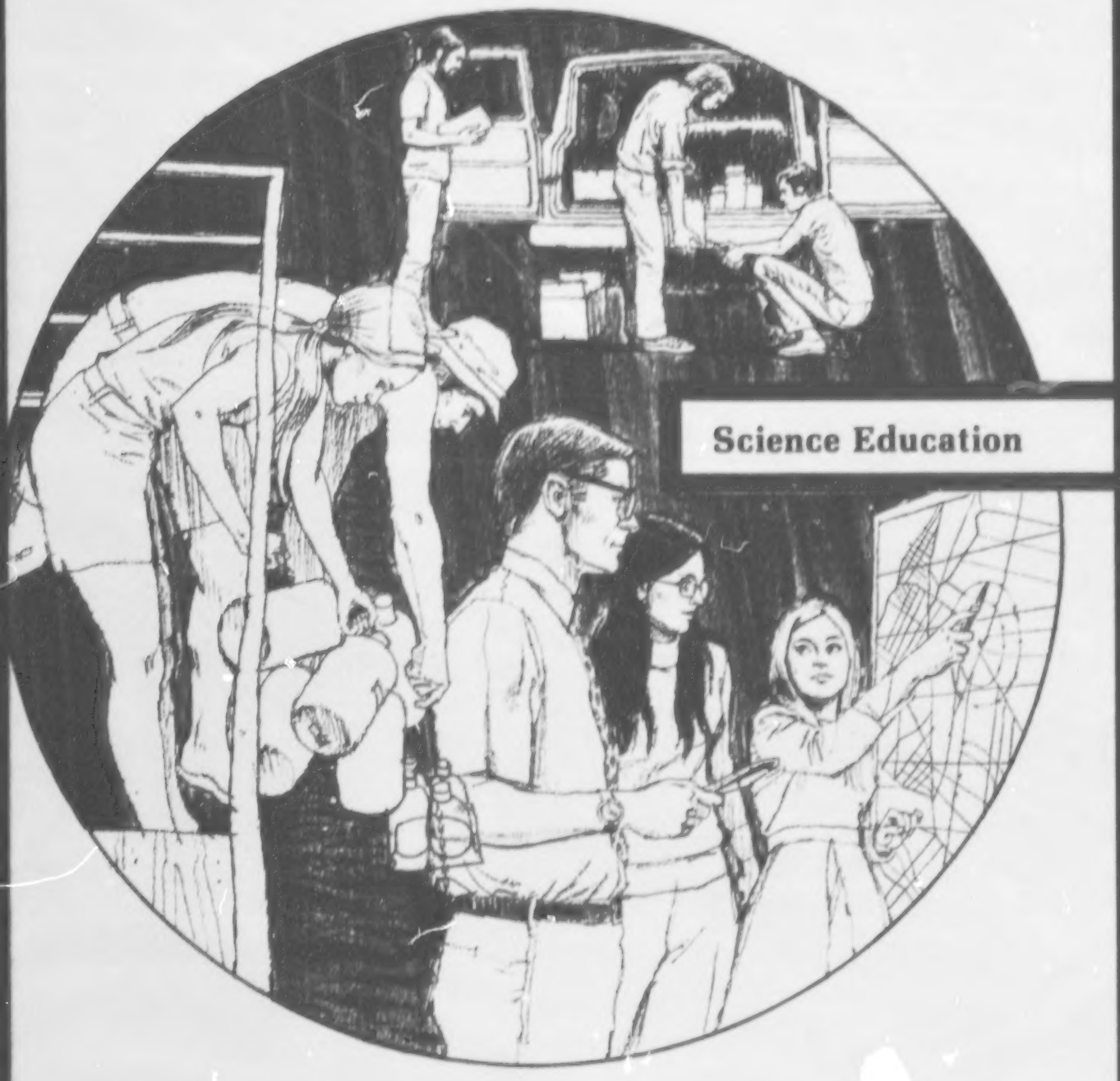
The local government science and technology program has been recognized as providing important examples for program development at both the Federal and local levels. The results from the "California 4-Cities" program, such as the Fresno vehicle replacement model, the Anaheim Cable TV program and the "Probeye" fire detector, are in the process of being transferred to other localities. The Tacoma, Wash. project which together with the city involves the Boeing Company, the Tacoma Boat Company, the University of Washington, and Battelle Northwest has done pioneering work in the development of new harbor multipurpose firefighting craft, transit demand routing models, court scheduling, and the design of fire equipment.

The Science and Technology Advisory Council to the Mayor of Philadelphia commenced full operations during the fiscal year with city, State, and NSF resources. The project has already made significant cost savings and operational effectiveness contributions in such areas as sludge disposal, enhancement of deteriorating property records, abandoned housing, street lighting, and graffiti.

Much of the work undertaken in fiscal year 1973 reflects activities designed to bring the resources of the Office of Intergovernmental Science and Research Utilization into direct support of RANN. This process was essentially completed during the fiscal year.

TEST ROAD BEING CONSTRUCTED WITH TREATED SLUDGE
Philadelphia, Penn.

As a result of developmental activities by the Mayor's Science and Technology Advisory Committee in Philadelphia, 30 years' accumulation of sewage sludge will be used in fill material—like this being laid for a test road—for interstate highway construction.



Science Education

Science Education

The Education Directorate has three major responsibilities. The first is to support and encourage those who are attempting to devise and implement new educational alternatives in science education. These alternatives are designed to enable a wider variety of individuals to perform a wider variety of tasks in the Nation's science-oriented labor force and, at the same time, better serve the needs of nonscientists by providing them with a better understanding of how science serves society. A second responsibility is to assure a reasonable and continuous flow of highly talented individuals into careers in science. The third responsibility is to provide factual data and an analytical basis for informed decisions leading to sound national policies and plans for the advancement and utilization of science.

In order to discharge these responsibilities in fiscal year 1973, the Foundation very sharply focused its efforts toward the resolution of a selected set of problem areas of concern to the academic community and to the Nation as a whole. These problems include the need to:

- emphasize qualitative rather than quantitative aspects of scientific training for career scientists;
- improve the cost effectiveness of science education through the development and implementation of improved educational materials and technologies, instructional strategies, and methodologies;
- assure the Nation of appropriate variety, flexibility, and numbers of scientific and technical manpower;
- provide improved science education for a broader range of students including the nonscientist;
- provide more adequate opportunities for continuing education outside the formal educational system for the Nation's technologically based society; and
- improve the Foundation's coverage of information on the supply and utilization of the Nation's science resources.

In seeking resolution of these problems the Foundation has, more than at any previous time, sought to pro-

Table 6
Education in Science
Awards and Obligations
Fiscal Years 1972 and 1973
(Dollars in Thousands)

	1972		1973	
	Number of Awards	Funds Obligated	Number of Awards	Funds Obligated
SCIENCE EDUCATION IMPROVEMENT				
Science Education Research, Development, and Demonstration				
Development of Alternative Instructional Methods and Materials				
Curriculum and Instruction Development	90	$3,469	72	$2,312
Undergraduate Instructional Materials	38	4,618	18	1,922
Graduate and Continuing Education Development	69	2,755	43	2,072
Experimental Models and Demonstrations				
Resource Personnel Workshops and Conferences	46	1,359	31	872
Comprehensive In-Service Teacher Education Projects	11	3,364	5	949
Pre-Service Teacher Education Projects	13	1,511	8	367
Technician Education Development	11	1,251	2	144
State and Urban System Projects	20	2,673	4	900
Instructional Improvement Implementation				
Training Educational Personnel for Implementation				
Secondary School Teacher Projects	519	16,140	280	10,411
Leadership Specialist Projects	25	2,190	24	2,044
College Teacher Projects	207	3,182	54	3,823
School System and College Implementation				
School System Projects	151	4,355	86	2,020
College and University Projects				
(1) Four Year College and University Projects	14	3,027	8	848
(2) Ethnic Minority College Projects	17	5,047	23	4,781
(3) Undergraduate Scientific Instructional Equipment Projects	372	2,881	213	1,578
Talented Student Program				
High School Student Projects	124	1,938	138	1,955
Undergraduate Student Projects	311	3,860	197	2,133
Student Originated Studies	103	1,896	87	1,095
Computer Innovation in Education	117	8,372	43	6,216
Total	2,205	73,388	1,364	46,925
GRADUATE STUDENT SUPPORT				
Graduate Fellowship Program	1,550	89,897	1,494*	$15,308,895
Graduate Traineeship Program	1,808	10,443	911*	
Total		20,340		

*Individuals—not grants

vide assistance in a way that would enable schools, colleges, and universities to develop their own capability for self-renewal in science education. This philosophy, while implicit in the Foundation's past Science Education Improvement support activities, was made explicit in each of the fiscal year 1973 programmatic thrusts and has been carried forward into plans for fiscal year 1974.

As an example of the increase in emphasis on this philosophy, the Foundation's support of activities to provide supplementary training for secondary school teachers of science and mathematics was in years past focused on increasing the subject-matter competence of the individual teacher. Gradually, emphasis has shifted from focusing solely on the teacher to greater concern for improvement within the teacher's school or school system. This shift manifested itself within the several program activities for in-service teacher training where, by the late 1960's, applicants for participation in summer institutes were required to document in their applications the manner in which attendance at an institute would have an impact upon the instructional program of their school or school system. Similarly, the growth of the Cooperative College-School Science Program during this period directly implemented this shift of focus. By bringing to a local school or school system the resources of a local college or university and applying these resources in a jointly planned effort to solve problems associated with upgrading science instruction at the pre-college level, instructional reform was effected. Activities at both the undergraduate and graduate levels of education also emphasized the development capacity to implement needed educational reforms.

While the Foundation's main concern now is with improving the way in which education in the sciences is done—including both its content and the manner in which it is presented or learned—it continues to have a responsibility for identifying and fostering the development of scientific talent at the graduate level. Traditionally the latter has been the main thrust. With recent changes in the availability of manpower within the scientific work force, however, particularly as it has been affected by shifting national priorities, greater emphasis has been placed on encouraging and assisting the Nation's science education establishment to respond more effectively and efficiently to shifts in national needs. A reduction in the direct support of graduate students in the form of fellowships and traineeships reflects this shift in emphasis.

In a year marked by stringent fiscal constraint on the part of the Federal Government, the Foundation shared in this effort, and funds available for Science Education Improvement were reduced to a level which represented approximately 64 percent of funds available for this purpose in the prior fiscal year. The consequences of this sharp reduction were felt in several ways. Support for Comprehensive In-Service Projects for pre-college teachers was terminated; the Technician Education Development activity was sharply curtailed, with only one institutional grant of this type being made this year; and a planned program of experimental projects designed to encourage institutional and individual initiatives in improving education in science was omitted. In addition to the termination or curtailment of activities, all but two program elements received severe reductions. These two elements were funded prior to receipt of notification of the total funding availability for the fiscal year.

During fiscal year 1973, the Foundation completed an extensive examination of each of its science education improvement efforts. The conclusions reached formed the basis for decisions necessitated by the unanticipated curtailment of funds and were invaluable in the formulation of plans for a much more sharply delineated program of operation for fiscal year 1974. The program critique was accompanied by an analysis of the Education Directorate's organizational structure and a reorganization of its operating divisions to create a more effective pattern of program management which would be responsive to the new program emphasis to be found in the altered fiscal year 1973 program and the more significantly restructured Science Education Improvement program plan for fiscal year 1974.

SCIENCE EDUCATION RESEARCH, DEVELOPMENT, AND DEMONSTRATION

In the early 1960's the Foundation launched a major effort in support of science curriculum improvement at the pre-college and higher education levels. This effort, which formed the base for a decade of improvement in science education, concentrated on standard curricula improvement within each science discipline. Over the past few years, however, there has been a growing awareness that these substantially discipline-oriented approaches are not adequate to meet the science education requirements of today. Furthermore, the cost of education in the United States is increasing at a rate greater than that of any other component of the economy except medical service. The need now is the variety and flexibility in the content of science

instruction and for improved instructional modes (delivery systems) in order to broaden the career options of graduates of the various levels of education, to prepare all citizens to live in a technologically oriented society, and to increase the efficiency and effectiveness of science education. To these ends, two main lines of activity were in force at the beginning of fiscal year 1973: the development of alternative instructional methods and materials; and experimental models and demonstrations. During the course of the year, a third mode of attack was added to the directorate when Technological Innovation in Education (previously known as Computer Innovation in Education) was transferred from the National and International Programs Directorate.

ALTERNATIVE INSTRUCTIONAL METHODS AND MATERIALS

Essential to the improvement of science education at all levels is the development and testing of new curricula, courses, materials, instructional aids, and methods of delivery. Emphasis continued on newer disciplines and interdisciplinary fields and on programs designed for the broader spectrum of students within the educational system, including those who wish to pursue continuing education.

Curriculum and Instruction Development

During the year the Curriculum and Instruction Development Program of the Division of Pre-College Education in Science was transformed into the Materials and Instructional Development Section. This change reflects the fact that for some years support has been given not just for the development of complete curricula but for the preparation of specific units of modules, which may fit into existing courses, and for instructional aids which may be addressed to teacher preparation, to special types of students, or to specific learning situations.

Among the grants of special interest was one to Florida State University for the initiation of a major curriculum development, the Individualized Science Instructional System, which will be based on roughly 125 modules in various areas of science addressed to students in grades 10 through 12. Conferences on curriculum development supported by NSF included: the Social Science Education Consortium conference considering the process of dissemination as related to curriculum developments; the Education Development Center's conference on unified mathematics and science at the secondary school level; a series of three study sessions held by the University of Indiana, the University of Maine at Orono, and Newton College of the Sacred Heart to consider the optimal characteristics of mathematics curricula in the K-12 range; and one by the Education Development Center for a summer study of new mathematics materials in the third to fifth grade range. These last four grants may well establish the main parameters of major developments over a period of the next several years in pre-college mathematics education.

Undergraduate Instructional Materials

Fiscal year 1973 witnessed a further exploration of promising nonconventional approaches to undergraduate science education—namely, modular instructional materials and computer-supported teaching.

In principle, individualization of instruction and economy are among major conceptual advantages inherent in the use of modules. Testing the applicability and validity of these

Table 7
Curriculum and Instruction Development (Pre-College)
Financial Support by Discipline
Fiscal Years 1972-1973

	Biological Sciences	Mathematics	Physics	Environ Sciences	Social Sciences	Inter disciplinary Sciences	Multi disciplinary Sciences	Other Science	Totals
Elementary									
1972	$27,000	$191,750	0	0	$49,400	$772,089	$702,011	0	$1,692,250
1973	0	438,225	0	0	86,506	59,577	22,462	0	606,770
Intermediate									
1972	178,450	22,800	0	0	0	5,000	601,123	0	807,373
1973	395,000	41,867	0	0	68,546	0	0	0	505,413
Secondary									
1972	78,650	165,200	$15,300	0	1,076,294	99,500	885,291	$11,000	2,328,145
1973	0	251,589	0	$360,980	769,394	1,141,954	497,907	0	3,021,824
Total									
1972	284,100	379,750	15,300	0	1,122,604	826,589	2,188,425	11,000	4,827,768
1973	395,000	731,681	0	360,980	924,446	1,201,531	520,369	0	4,134,907
Percentages									
1972	5.9	7.9	0.3	0	23.3	17.1	45.3	0.2	100.0
1973	9.5	17.7	0	8.7	22.4	29.1	12.6	0	100.0

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ideas in an undergraduate environment requires a sufficiently large and varied pool of modules in a single discipline. Thus, support was continued for two distinct but complementary projects relating to biology. One—the Minicourse Development Project of the Biological Sciences Curriculum Study Group—is working on 250 self-contained multimedia packages spanning many of the facts, theories, and methodologies common to modern biology. BIO-TECH, the other, is producing about 150 skills-oriented modules placing primary attention on operational techniques.

Several different aspects of computer-supported instruction have received grants. At the University of Illinois, interactive tutorial lessons for introductory and organic chemistry are being developed for use on the PLATO (Programmed Logic for Automatic Teaching Operations) system. Continued support has been awarded to the University of Texas, Austin, and to the Computer Aids for Chemical Engineering (CACHE) project of the National Academy of Engineering. The former is of interest not only because the teaching materials are being prepared in some 18 academic departments, but also because it represents a program to plan, implement, evaluate, and analyze large-scale, coordinated, university-wide use of computer-based instruction. The CACHE committee's work is directed also towards the use of new techniques for distributing computer-assisted instruction and other nontraditional materials, and towards analyzing the benefits and disadvantages of alternative means of providing needed computer use in professional education in chemical engineering.

Graduate and Continuing Education

Activity in alternative doctoral degree programs, first initiated 3 years ago, resulted in awards to the University of California, Los Angeles, the University of Alaska, and the Association of American Geographers. While the grant to UCLA supports the continued development of the practice-oriented Doctor of Environmental Science and Engineering, assistance was provided to the University of Alaska for the experimental initiation of external M.S. and Ph.D. programs aimed primarily at already employed individuals. To obtain information important to other universities considering the establishment of such programs, the university will closely examine participant characteristics, problems encountered in equating external and internal degrees, means for maintaining high academic standards, and factors contributing to meaningful employer involvement. A quite different problem is attacked by the Teacher Development Project of the Association of American Geographers, which is coordinating a set of pilot programs at the University of California, Berkeley, the University of Iowa, the University of Colorado, Clark University, and the University of Illinois. All share the goal of improving the preparation of prospective college teachers of geography, but each approaches it in an individual manner that ranges from the use of seminars to training in course and curriculum improvement.

One response of universities to meeting newly perceived manpower and skills needs in the Nation has been the development of special master's degree level programs. Some of these are predicated on unusual subject-matter combinations, and several incorporate internship and other practical experiences. Patterned after the Agricultural Extension Service is a master's degree program in urban economics initiated by the University of California, Santa Barbara, that will couple on-campus academic instruction with supervised service in a public sector agency. Attention to more technologically oriented approaches to meeting societal needs is being given in master's degree programs in energy systems engineering at the University of Texas, Austin, in manufacturing engineering at the University of Massachusetts, in professional engineering at Oklahoma State University, and in applied mathematics at Harvard University.

Continuing education for scientists and engineers formed another program focus. Creation and testing of random-in, random-out modular packages dealing with techniques of experimental physics useful to scientists and engineers employed locally is the subject of a University of Maine project, and New York University is experimenting with an intensive short course format. The University of Southern California, with its interactive instructional television service, and the Georgia Institute of Technology, with its audiographic learning facility, have initiated efforts to capitalize on and assess the applications of technology to achieve effective and

Table 8
Graduate and Continuing Education
Fiscal Year 1973

	Alternate Doctoral Degree Programs		Master's Degree Programs		Continuing Education and External Degree Programs	
	Number of Grants	Total Amount awarded	Number of Grants	Total Amount awarded	Number of Grants	Total Amount awarded
Engineering	1	$150,190	3	$184,300	2	$149,945
Multidisciplinary science	0	----	1	----	1	14,950
Mathematics	0	----	1	49,949	0	----
Multidisciplinary science	0	----	0	----	1	171,070
Physical sciences	0	----	0	----	1	35,660
Social sciences	2	97,860	1	181,635	0	----
TOTALS	3	$248,050	7	$415,884	5	$371,625

economical delivery of continuing education to members of the scientific work force.

Projects to generate nonconventional courses include the George Washington University effort in urban transportation, the Florida Technological University sequence in chemical process development, and the Colorado State University set of modular short courses in chemical instrumentation. The latter-most, for example, is preparing a series of offerings for non-chemist students who must use the principles, practices, and instruments associated with chemistry in their own graduate programs.

EXPERIMENTAL MODELS AND DEMONSTRATION

New educational materials and methods of instruction move into general classroom practice only if prospective users have an opportunity to see them in action, and are provided with such evaluations of their effectiveness and estimates of cost as will enable them to judge for themselves the benefits to be derived. To provide such working demonstrations and to promote widespread knowledge and understanding of them, a variety of activities is supported.

Resource Personnel Workshops and Conferences

Resource personnel projects are designed to inform pre-college administrative and teaching personnel about curricula with which they are unfamiliar. These projects may include short courses, which provide the background necessary for decision-makers — principals, directors of education, and other school administrators—to make informed decisions on whether or not to adopt specific curriculum changes for their school systems. They also give supervisors and administrative personnel background to support their teachers should these new curricula be implemented. Some of these projects (workshops) bring together teams consisting typically of a science educator, a school administrator, and a teacher. Each team is provided in-depth knowledge concerning the philosophy, content, and successful instructional modes related to one or more curricula, after which the team assists its own school district in adopting curriculum improvements.

During fiscal year 1973, proposals were received for support of 70 resource personnel workshops and 40 administrators' conferences, requesting $4.73 million and $0.95 million, respectively. The 20 administrators' conferences funded for a total of $281,829 and 11 resource personnel workshops for $653,400 provided varying degrees of background or training for more than 1,600 participants.

Comprehensive In-Service Teacher Education Projects

The Comprehensive Grants Program, which was terminated in fiscal year 1973, sought "to foster a lasting interaction between colleges and universities and the teachers in the region they served. The approach was for institutions to provide in-service teacher training opportunities explicitly matched to the needs of their schools while modifying the regular programs of the sponsoring university so that they were more responsive to teacher and school needs. These changes showed evidences of persisting beyond the intended 4-year life of the grants.

Two factors necessitated the termination of the program. First, funding limitations required a reassessment of NSF priorities and, as a result of that activity, it was determined that the Foundation should support only that teacher training which fostered the implementation in schools of major course and curriculum development, a policy central to the program plan for fiscal year 1974.

Five final supplemental grants were made to institutions to aid them in phasing down their activities and to prevent them from abruptly terminating programs to which personnel at the university and teachers had commitments. These activities were at the University of Mississippi, the University of Notre Dame, the University of South Dakota, the University of Wyoming, and Virginia State College.

Pre-Service Teacher Education

In recent years the Foundation has stressed improvements in the pre-service education of elementary and secondary school teachers as an efficient way to improve science education on the pre-college level and an economical way to decrease the need for the early retraining of teachers.

To be effective in producing significant change, this approach usually requires extensive restructuring of the entire program, through which all students in the institution who are preparing to teach will receive their education, and coordination of effort between higher education and pre-college schools.

Fourteen formal proposals were received during fiscal year 1973 requesting a total of $3.3 million. Four awards were made with total obligations of $400,000.

A project at Indiana University is developing a model program for the education of prospective elementary school teachers in the teaching of mathematics utilizing an activity-oriented laboratory setting. The experience of the prospective teachers includes education in mathematics teaching on the campus that totally integrates the study of content and method in a mathematics laboratory setting, and observation of how children learn and teaching experience in a model school utilizing the mathematics laboratory approach.

Regional, State, and Urban Pre-College Systems

The Foundation supported experimental projects involving the coordination of the efforts of Federal, State, and local governments, and of private agencies in meeting a specific mutually agreed-upon educational need or solving a specific problem in science education in a region such as a State.

Supplemental grants were made to continue two projects: (1) for the Systems Approach to Science Education in Delaware to support its third year of operation, and (2) for the Oregon System in Mathematics Education to support its second year of operation.

The Delaware project is a Statewide cooperative effort of the University of Delaware, Delaware State College, Delaware Technical and Community College, the Delaware State Department of Public Instruction, and the 26 school districts of the State. The general goal of the program is the improvement of the quality and variety of science and mathematics programs on the pre-college level with emphasis on the middle grades. The efforts of the project are concentrated in schools and classrooms rather than colleges and universities.

The Oregon Project is a Statewide cooperative effort which aims to develop exemplary mathematics programs in elementary and secondary schools taking into account demography, organization, and pupil needs. Activities of the project include those designed to develop leadership personnel, improve teacher education programs, strengthen professional organizations, and improve communication among system components.

A third grant was made in 1973 to assist in designing a program, utilizing systems design concepts, for ascertaining the earth science educational needs and priorities of Oklahoma and meeting those needs. The total funds obligated for the three projects was $1.0 million.

TECHNOLOGICAL INNOVATION IN EDUCATION

The U.S. system of education is placing ever increasing demands on the Nation's resources. The fraction of the GNP devoted to all educational expenditures (public and private, from kindergarten through graduate school) has risen steadily since the end of World War II—from about 3 percent to about 8 percent in 1971-72. Nonetheless, the educational needs of certain elements of our population continue to go unmet, and the quality of instruction throughout the system is very uneven. Technological Innovation in Education has as its goals improving the quality of instruction (with special emphasis on science education), improving the efficiency of instruction, and improving access to specialized educational needs through the application of modern computer and communication technologies. In fiscal year 1973, approximately $6.3 million was awarded toward these ends to academic and other nonprofit organizations.

Development of the PLATO IV system of computer-assisted instruction (CAI) continued in preparation for a 2-year, large-scale field test and evaluation. This system is designed to provide highly appealing CAI simultaneously to thousands of widely scattered students, using a single large computer system and graphic terminals invented and perfected at the University of Illinois. The first 250 (plasma panel) terminals have been delivered and installed at locations throughout the country.

A student ponders a problem presented on a PLATO IV terminal, part of a computer-assisted instruction system being prepared for a 2-year, large-scale field test and evaluation. To date, 250 such terminals have been installed throughout the country.

Concurrently, the Foundation is sponsoring the development and field testing of the TICCIT (Time-Shared Interactive Computer Controlled Information Television) system of CAI developed and designed by the MITRE Corporation and Brigham Young University to provide highly efficient instruction in community colleges for such introductory courses as English and mathematics. Efficiency will be obtained by exploiting minicomputer and television technology (to serve over 100 student TV terminals simultaneously), and through learner-controlled courseware which simplifies system design, courseware authoring, and student/computer interaction.

Development and field test of the PLANIT (Programming Language for Interactive Teaching) machine-independent system of CAI was completed during fiscal year 1973. The design objectives—to produce a sophisticated system capable of being installed and operated effectively on a very wide variety of existing computing equipment—has been achieved, based upon preliminary results from a field test conducted at Purdue University. A conference will be held early in fiscal year 1974 during which the system will be explained, demonstrated, and distributed.

Research and development continued into computer-based techniques for optimizing student performance. Investigators at Stanford University believe that they can not only improve student performance (by 50 to 100 percent) for elementary reading and mathematics, but also predict such improvements for each student on the basis of the student's performance without CAI during the previous year and his performance after testing with only an hour or two using CAI. A modest experiment was begun to provide CAI of this sort to American Indians at a pueblo in New Mexico. Data are incomplete, but results indicate significant improvements in student performance and attitude, and thus have generated considerable enthusiasm for the project from officials of the school and the community who are taking steps to continue it at local expense after fiscal year 1974. The project could serve as a valuable model for other widely scattered communities of Indians.

All major universities and many colleges now provide computing services for faculty and students. While major computer-based curriculum efforts are only just beginning, one major obstacle in sharing instructional programs is the complexity of the new technology. Since universities use different machines and computer language and operate their services in a variety of formats (batch versus interactive), it is difficult to directly exchange instructional programs. Further, the variety of the disciplinary content creates numerous documentation problems. In order to increase the potential for widespread use of materials and at the same time reduce the time and costs related to program exchange, several universities have initiated a major cooperative effort to study and overcome this problem.

CONDUIT (Computers at Oregon State University, North Carolina Educational Computing Service, Dartmouth College, and the Universities of Iowa and Texas at Austin) is a consortium of five regional networks involving 100 colleges and universities with an enrollment of approximately 300,000 students, and is organized to study and evaluate the transportability and dissemination of computer-related curricular materials for use in undergraduate instruction. The goals and procedures of CONDUIT are determined by a Policy Board, which consists of the director of each regional computer network. CONDUIT Central, located at Duke University, coordinates network activities and maintains the CONDUIT library. It also creates and distributes videotaped seminars and self-instructional computer-related materials.

In fiscal year 1973, 12 grants were awarded to establish a regional educational computer network for colleges in Central Mississippi under the leadership of Jackson State College. Five of the participating institutions are private 4-year institutions; three are State-supported senior institutions; and four are 2-year colleges. The Regional Cooperative Computing Activities Program under which the above awards were made was phased out in this fiscal year. An analysis of the impact and cost of regional computer networks on undergraduate instruction is contained in a report published by the University of Iowa entitled "A Study of Regional Computer Networks."

Other supported studies included the examination of various communication technologies such as broadband two-way cable systems, specialized common carriers, stationary satellite, and optical communication links, with a view to assessing their potential for various nonconventional educational telecommunication services.

INSTRUCTIONAL IMPROVEMENT IMPLEMENTATION

Two approaches are used to promote the implementation of instructional improvement in the Nation's academic institutions: development within the schools and colleges of a corps of teachers adequately trained to install and carry out the needed programs, and partial funding of the implementation of new courses or curricula in a limited number of institutions, which will serve as models for consideration by others.

TRAINING EDUCATIONAL PERSONNEL FOR IMPLEMENTATION

The projects supported under this program element are designed to improve the capability of science faculty to implement new science education programs, such as new and improved science curricula and teaching modes. Enabling instructional personnel to be more responsive to the needs of their schools is a key requirement in the NSF effort to stimulate constructive changes throughout the U.S. education system. Since the nature of the educational process varies from level to level, there are activities directed at both pre-college and post-secondary personnel.

Secondary School Teacher Projects

As in previous years, the Foundation supported a variety of projects to help meet the needs of participating teachers and their schools. Activities took place in both the summer and the academic year, and the formats were varied. Some focused on acquainting teachers with new course materials and assisting them in installing these new materials in their classrooms, others aided teachers in preparing their own materials, still others involved field work. Throughout all these activities, however, changes in style and content were introduced in preparation for a complete restructuring of the Foundation's pre-college education program scheduled for fiscal year 1974.

The Summer Institutes supported in fiscal year 1973 encompass some projects in each of the formats mentioned above. Participants in the project at the City College of New York concentrated on the process of studying environmental science as well as the content. Study guides and modules will be developed in the curriculum development core courses. At Seminole Junior College (in cooperation with the University of Oklahoma), teachers from disadvantaged secondary schools in a five-county region in east-central Oklahoma will prepare to introduce chemistry into schools from which it has been missing, largely because of a lack of laboratory equipment. They will spend 2 weeks in May in hands-on instruction for the building of "TOPS" and "Armchair" experiment devices. These make student experimentation and demonstration in chemistry possible at costs far below those of the usual school laboratory work. After 2 months on their own, participants will return to the campus for study and practice in the utilization of the materials. Follow-up sessions during the academic year will provide teachers with the opportunity to exchange ideas after utilizing materials in their classrooms.

In-Service Institutes have, in the past, provided part-time training opportunities for teachers during the academic year while they were carrying on their classroom teaching during the regular school day. Funding limitations in 1973 made it impossible for the Foundation to put into effect its initial program plan. The In-Service Institutes, which have historically been funded during the second half of the fiscal year, were sharply curtailed, with support being given to only 10 projects with multiple-year commitments and to 24 projects in combination with Summer Institutes.

In fiscal year 1973, Academic Year Institutes were converted into Leadership Development Projects (LDP), which more accurately denotes the thrust of the projects supported. Participation in an LDP is intended to enhance the potential of the participating teacher-leaders for effecting changes in the science and mathematics programs in their schools. Two nationally oriented projects and 22 regionally oriented projects were supported in fiscal year 1973. Of the former, one is intended for in-service science supervisors and one for resource personnel in mathematics. Because of changes in emphasis for the future, fiscal year 1973 marks the last year that full-time academic year support will be given for study of this nature.

In fiscal year 1974, teacher institutes in their current form will be phased out, but the mechanisms for teacher training will become a part of a broader spectrum of activities to foster the implementation of major curriculum and course developments in school systems. The Cooperative College-School Science Projects, described below, will also become a part of this refocused effort to bring change to elementary and secondary school classrooms.

College Teacher Projects

Institutes and short courses offered college teachers the necessary information, materials, and techniques for developing and implementing desirable changes in their undergraduate programs in science. The college teachers whose participation was sought were those most likely—because of their training, experience, and commitment—to introduce innova-

tions in subject-matter content and instructional strategies, at their home institutions. The projects were concerned with recent information not yet generally included in curricula or with recently developed educational strategies showing promise of more efficient delivery of undergraduate science instruction.

In keeping with current interests, the 84 projects involving some 4,000 college teachers are better characterized by examples of the environmental and societal issues to which they were directed than by identification of the disciplinary areas being applied: resource allocation, impact of urbanization, economics of pollution, food production in natural and managed ecosystems, geologic hazards, genetic engineering, ecological adaptation, space utilization, and environmental health. Some projects typically provided training in the use of educational technologies that place responsibility on the student for the direction, pacing, and mastery of his learning: computer-assisted instruction, programmed learning, and autotutorial procedures.

SCHOOL SYSTEM AND COLLEGE IMPLEMENTATION

The objective of this group of activities is to help various educational institutions organize their resources for more efficient uses and to spread the benefits of modern educational technologies and structures. NSF support under this program element fosters the coordination of college, high school, and elementary school science education programs so as to minimize the disjunctions between successive levels. Internal changes within institutions aided by this support are expected to result from the interaction process, making the entire ladder of educational progress for students more coherent. Changes at the level of higher education are facilitated through experiments in restructuring of formal educational institutions. Various methods of change are encouraged, such as the creation of innovative environments in a single discipline, interdisciplinary overhaul in a single institution, extensive collaboration among institutions, and merging of a variety of instructional approaches and extra-institutional settings into flexible learning environments.

Cooperative College-School Science

The Cooperative College-School Science (CCSS) program consists of projects of 1 to 3 years designed to improve science and mathematics courses and curricula within a cooperating school system.

Eighty-one projects were funded in fiscal year 1973. This is considerably fewer than the number supported last year (142). The number and quality of proposals to assist the elementary schools has improved steadily since 1967, so that of the 81 projects supported, 43 (53 percent) were for elementary schools as compared with 12 of 65 (21 percent) in 1967. Eighty-three percent were to improve instruction in science; the rest were in mathematics.

Since 1968, a considerable number of proposals has been received to improve science and mathematics education for the disadvantaged, several of which have been supported. A basic assumption in each program is that poor motivation is a significant cause of low achievement by the culturally disadvantaged, and that success in a high-status subject will raise a student's self-image and raise his career goals. One such project at Fort Lewis College in Colorado will assist in implementing an activity-centered and inquiry-oriented elementary mathematics curriculum into eight Navajo Indian schools in Colorado and Arizona. Twenty-five teachers and five teacher-aides will be trained to provide Navajo children with experiences which will allow them to better formulate mathematics concepts. A second project, at Morris College in South Carolina, will provide educationally and culturally disadvantaged rural students with individualized educational experiences designed to enable them to progress at their own rate.

The Cooperative College-School Science Program will no longer be supported as an independent activity. The mechanism of cooperation between school systems and colleges and universities assisting them to make improvements in their courses and curricula will become a part of the curriculum implementation activities supported by the Division of Pre-College Education.

College Science Improvement

Fiscal year 1973 was the concluding year for new awards for individual institutional projects in 4-year colleges (COSIP A) and for interinstitutional projects in 4-year colleges (COSIP B). Consistent with the changing nature of the NSF science education improvement activity, the projects supported emphasize experimentation with alternative structures for undergraduate education. During the year 28 proposals, requesting a total of $8.2 million, were considered for support. Nine awards were made for a total of $1,277,155.

A major experiment at Austin College in Sherman, Tex., jointly funded by the National Endowment for the Humanities, involves restructuring of the entire institution. Key ingredients of Austin's unique approach to undergraduate education are a redefinition of the roles of students and faculty which places more responsibility on the student, a greater use of educational technology to incorporate the latest in educational techniques environment, and a use of methodologies from the behavioral sciences in a conscious effort to aid students in their personal and human-to-human interactional development.

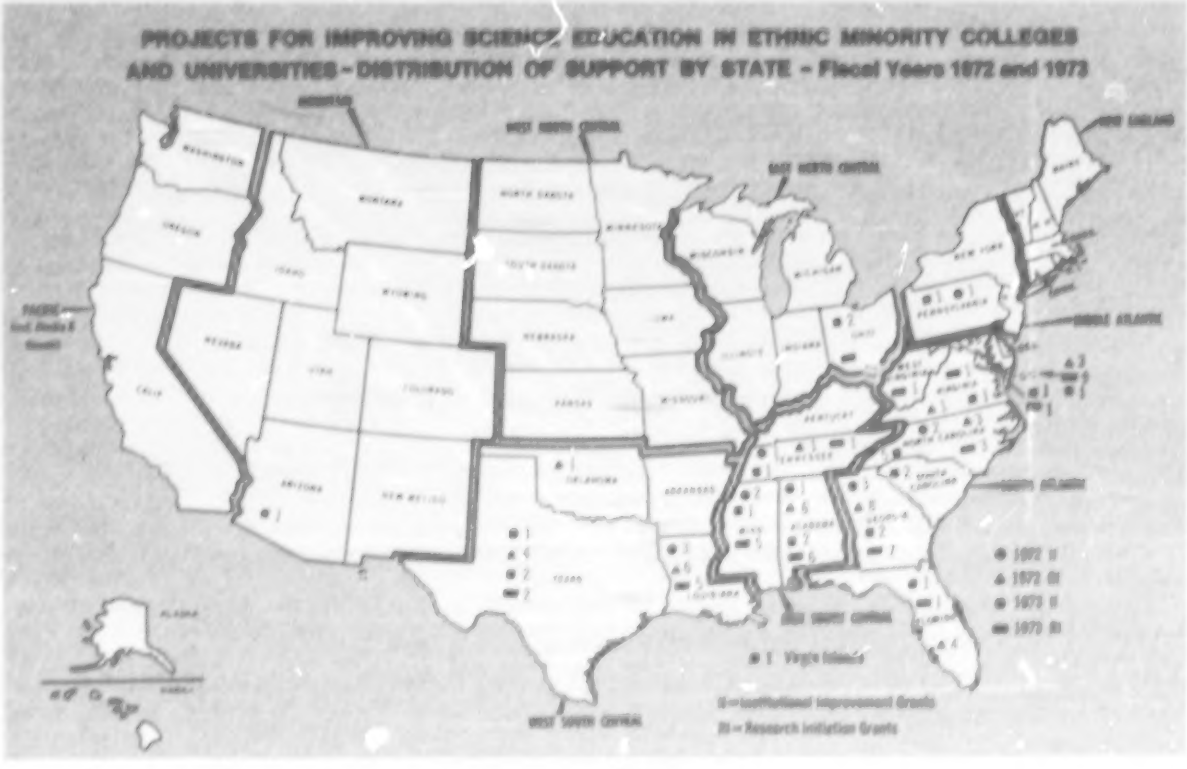
Two institutions are being provided initial support in their

decision to develop instructional delivery systems that utilize learning modules on a large scale. At Evergreen State College, Olympia, Wash., the self-pacing modular units developed are being integrated into a highly unstructured curriculum with the student-faculty performance contract as its basis. In the fall of 1973, when the first students arrive at College IV of Grand Valley State College, Allendale, Mich., there will be available a single curricular matrix of interconnected, auto-instructional learning modules, aimed at complete individuality of instruction.

At Oberlin College in Ohio, faculty of the mathematics and psychology departments are cooperatively investigating the causes for minority student difficulties in mathematics, with special emphasis on diagnosis of prior competence, reduction of inhibition, and motivational development.

This was the second year of Foundation support for those colleges and universities that have traditionally and historically served ethnic minorities and that have themselves been disadvantaged in the financial support of their science education programs (COSIP D). This support is designed to help the Nation work towards equal educational opportunity and to capitalize on the unique national resource represented by this group of institutions. The major funding is directed to institutional improvement grants to upgrade the institutions and their course offerings. Eighteen grants were awarded in fiscal year 1973; 10 of these were to public and 8 to private institutions. Eligibility has been expanded recently to allow participation not only of the traditionally "black" colleges but also of those serving primarily American Indian and Spanish-speaking minorities.

Another category of support administered by the COSIP D staff is the Research Initiation grant for support of scientific research by faculty members at ethnic minority institutions. Forty-four such grants were made in fiscal year 1973 to a total of 24 institutions, with the largest number (9) going to Howard University.


PROJECTS FOR IMPROVING SCIENCE EDUCATION IN ETHNIC MINORITY COLLEGES AND UNIVERSITIES - DISTRIBUTION OF SUPPORT BY STATE - Fiscal Years 1972 and 1973
1 Virgin Islands
I = Institutional Improvement Grants
R = Research Initiation Grants

Instructional Scientific Equipment

In fiscal year 1973, this support activity made 213 awards to assist 2- and 4-year colleges and universities in implementing specific course and curriculum improvements through the purchase, on a matching fund basis, of necessary equipment. Of these, 66 percent were in natural science and mathematics, 18 percent in engineering, 10 percent in social sciences, and 6 percent were multidisciplinary. Ten percent of the awards went to 2-year institutions. The 1,301 proposals received in fiscal year 1973 requested funds roughly seven times the amount available for allocation.

TALENTED STUDENTS

The three activities directed to talented students share objectives related to the student, to the educational system, and to the Nation. First, students are provided with an intensive introduction to scientific research—one that allows, indeed forces, them to distinguish genuine interest and talent in science from mere intellectual or technical facility in the field. It is expected that such experience will provide them with a sound basis for deciding whether they should continue in science or change fields. An early and informed decision can save money and time for both the student and the educational system that serves him. Second, the projects supported under this rubric are designed to encourage schools and colleges to alter their "regular" science programs to include more activities that give students an opportunity for choice, that place upon them more responsibility for their own learning, and that allow them to express in productive ways their concern for the well-being of the Nation by applying scientific and technological expertise to the study of significant societal problems. A final and related objective is the identification of future scientific leaders and the conservation of science talent.

Student Science Training

The Student Science Training Program (SSTP) provides high-ability secondary school students who demonstrate a strong commitment to science with an opportunity to participate in research and special courses during the summer and, in some cases, during the academic year. As a result, their scientific development is accelerated and they are provided with a better knowledge base from which to make career decisions. In recent years, the goals of the SSTP program have been broadened in an attempt to develop a feedback from the intensive summer experience of the student to the instructional program at the high school to which the student returns.

This year 128 proposals were supported at a funding level of $1.9 million for 4,800 students. Projects covered a wide spectrum of activities in the natural and social sciences and included several with a strong technological emphasis. For example, a program at the University of Virginia in Charlottesville provided students with a detailed introduction to the chemical process industry and the design of a simple chemical plant. Minority groups and disadvantaged students at the University of Oklahoma Health Science Center in Oklahoma City participated in medical research under the supervision of faculty members and became more aware of options and career opportunities available to them in the health sciences.

Thirty-two percent of the projects supported were designed especially for students with limited educational opportunities. Students in this category have demonstrated high potential, but come from secondary schools in which training is inadequate.

Undergraduate Research Participation

Undergraduate Research Participation is a sophisticated apprenticeship system under which one or two talented pre-baccalaureate students become junior colleagues of a productive scientist on a project that permits the student to rapidly develop a significant degree of independence. Since 1959, the Foundation has used this mechanism to afford some 65,000 undergraduates this sort of experience, and to bring the merits of this educational approach to the attention of thousands of science departments. In 1973, support for 1,308 participants in 191 projects was awarded to 155 institutions throughout the country.

Student-Originated Studies

This program element carries the notion of student responsibility for learning even further than the two just described by requiring that the research ideas be student-conceived, proposals student-written, and projects student-managed. The program's success over its 3-year history is a testimony to the soundness of its philosophy. The news media have brought broad public attention to many projects, and the flourishing demand for their final reports indicates that local and State governments, Federal agencies, and environmental interest groups find the research results to be of value in analyzing local problems of broad societal concern. In fiscal year 1973, grants were awarded to 73

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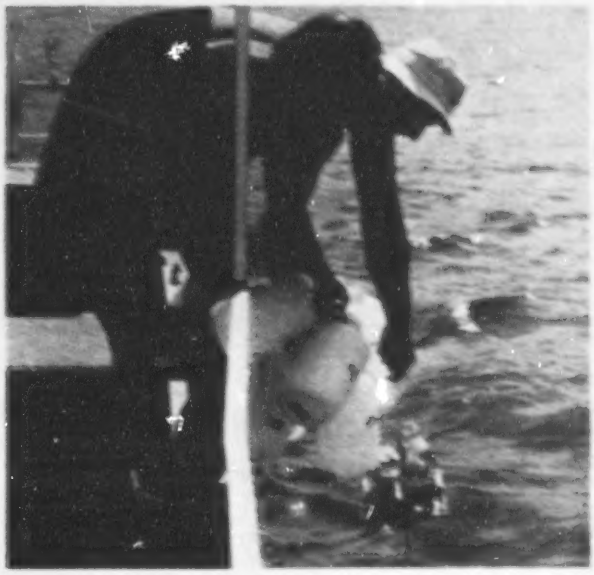
colleges and universities supporting 79 student projects involving more than 700 undergraduate college students. Among the problems these students addressed were:

- a search for an effective process to make paving materials from wood industry wastes;
- development of a device to accelerate communication in mute, severely handicapped children; and
- the determination of property assessment differentials in a metropolitan area.



Three Student-Originated Studies projects. (*Left*) At Ripon College in Wisconsin, students collect lake water for tests of primary productivity of the lake as an index of pollution in a region of locally dense population. (Right) Students from the Colorado School of Mines are making field checks of Clear Creek waters preparatory to laboratory analysis for heavy metal pollutants from extensive mine tailings in the area. (Bottom) At Seton Hall University in New Jersey students look for possible correlations of trace metals in the atmosphere with the concentrations of these metals in the blood of children living near air sampling stations in Newark.

GRADUATE STUDENT SUPPORT

The primary objective of graduate student support is to provide a reasonable and continuous flow of highly talented individuals into science careers. Selection on the basis of ability identifies and recognizes the most capable graduate students and establishes a national norm for the assurance of quality of education at the graduate level.

Graduate Fellowships and Traineeship

Fiscal year 1973 represented the second year of operation of the Graduate Fellowship Program's new system of 3-year awards. This program, which was restructured beginning with fiscal year 1972, now has the following characteristics:

- Eligibility to apply for a Graduate Fellowship is limited to students who by the fall term following announcement of the awards will not have completed more than 1 year of graduate study.
- New fellowships must be activated not later than the fall term following the announcement of the award, but the remaining 2 years may be held during any 2 of the following 4 years.
- All fellowships carry a stipend rate of $3,600 per year, with an associated cost-of-education allowance for the U.S. fellowship institution of $3,000 per year.

The total number of new applicants for 3-year fellowships (5,713) represented an increase of 14.1 percent from the corresponding figure of a year ago (5,005). This increase is mostly attributable to the decrease in Federal support available to beginning graduate students. The total of 457 new awards this year represented a success ratio of slightly less than 8 percent. Honorable Mention—defined as an applicant fully worthy of a fellowship had sufficient funds been available—was accorded to an additional 1,913 of the 5,713 new applicants.

The 457 fellowships were awarded in the following sciences: 62 in mathematics, 63 in engineering, 99 in the physical sciences, 100 in the biological sciences, and 133 in the social sciences and psychology. Of the 457 awards, 110 were made to women based on applications from 1,540 women.

This was the final year in the phase-out of the Foundation's Graduate Traineeship Program. Awards of 911 continuation traineeships were made to 172 doctoral-granting institutions. Fiscal year 1970 was the last time new traineeships were awarded.

SCIENCE RESOURCES AND POLICY STUDIES

The overall objective of the Foundation's programs in science resources and policy studies is the development of the factual and analytical basis for national planning and policy formulation in the area of science and technology resources. The program encompasses the two closely related activities of analysis and data collection related to science and technology issues. The information developed through these studies is used in arriving at decisions concerning the NSF and national science efforts.

SCIENCE RESOURCES STUDIES

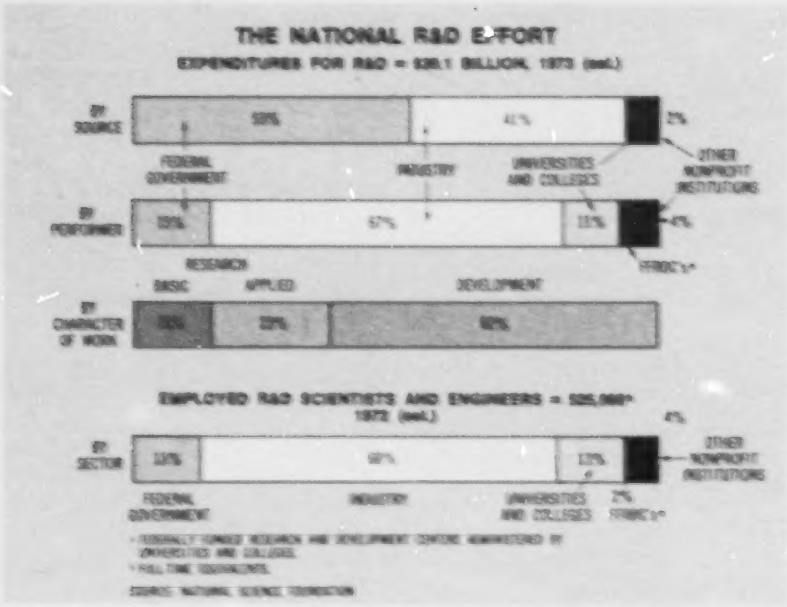
Science resources studies of general interest issued during the year are listed in Appendix E. A few are summarized below.

National Patterns of R&D Resources

Expenditures for research and development in the United States are expected to exceed $30 billion in 1973, a 3-percent increase over 1972. Federal R&D programs will remain just below the $16 billion level, only slightly more than the 1972 total. These and other data obtained through periodic NSF surveys of all sectors of the economy are available in the report *National Patterns of R&D Resources*. The report points up a changing pattern in R&D funding including the decline from the 13.7-percent average growth rate in R&D expenditures during 1953-61 to an average annual increase of 4.2 percent over the last 6 years, 1967-73. During this latter period, the non-Federal portion of R&D funding shifted from 39 percent to an estimated 47 percent of the total.

Science Manpower

Doctorates awarded in science and engineering fields during fiscal year 1972 numbered 19,522, in comparison with the fiscal year 1971 total of 19,574. The decrease, although slight, was the first in several decades. Even with this reversal in the long-run upward trend, awards in fiscal year 1972 were three times the number of fiscal year 1960 and nearly twice that in fiscal year 1965. Nearly all natural



science and engineering fields declined from 1971 to 1972. Social science fields, though increasing, rose considerably less than between fiscal year 1970 and 1971. Doctorates awarded in education, professional fields, and the arts and humanities continued to increase.

Several indicators evidence a continuing improvement in the employment situation for scientists and engineers. Surveys of recruitment and placement activities forecast an improving employment situation in 1973, especially for new graduates (and 1972 was improved over 1971).

Science and Technology in the Innovative Process

A contract study exploring further the relationships between science and technology and the innovative process was performed by the Battelle Columbus Laboratories. It reviewed the development of the heart pacemaker, hybrid grains, input/output economic analysis, electrography, and organophosphorous insecticides and extended earlier studies of the video tape recorder, magnetic ferrites, and oral contraceptives, documenting the chronological and systems relationships between basic research, applied research, and development in these highly important recent innovations.

The study published as *Interactions of Science and Technology in the Innovative Process: Some Case Studies* and in summary form as *Science, Technology, and Innovation*, should prove of interest to those involved with the stimulation of technological innovation.

Advisory Committee Recommendations

In the fall of 1972, the Director appointed an advisory committee to review the program of science resources studies and provide advice and guidance for future direction and emphasis. The committee, chaired by Dael Wolfe, included representatives of industry, academic institutions, professional societies, research institutes, and other Government agencies. The committee completed its review and presented a report in the spring of 1973, making a number of recommendations.

As program funds and available staff permit, the committee's proposals will be implemented in fiscal years 1974 and 1975.

SCIENCE POLICY STUDIES

Activities of the National Academy of Sciences and National Academy of Engineering

The Foundation continued support for the National Academy of Sciences Committee on Science and Public Policy in its examination of priorities in science and identification of opportunities in science, and other activities. The Committee on Remote Sensing Programs for Earth Resources Surveys was particularly active, establishing several subpanels in order to facilitate its work. Funding support by NSF and the Advanced Research Projects Agency is permitting the National Academy of Sciences Committee on the Survey of Materials Science and Engineering to determine how materials science and engineering will contribute to the national well being. The first two volumes of their report have been completed.

Liaison also continued with the Committee on Public Engineering Policy of the National Academy of Engineering, which renders advice and assistance to NSF on engineering status and policy. Completed studies are: "Federal Support of Applied Research" and "Priorities in Applied Research."

The Foundation also supported the Academy's Committee on Radio Frequencies, the body that represents the United States in international unions on matters relating to radio frequency spectrum assignment and utilization. The activities of this com-

mittee have been increasing during this fiscal year, primarily in response to the added pressures for spectrum assignment due to increased use of satellite telemetry.

Other Policy Activities

Various inquiries and evaluations continued as part of the Foundation's policy planning effort. Published during the year were the third and final volumes of *Science, Technology and Public Policy: A Selected and Annotated Bibliography*. Contracted research at the Massachusetts Institute of Technology continued to investigate possible policy alternatives for science.

Evaluation Activities

An activity completed during fiscal year 1973 entailed the development of an operational computerized budget allocation and impact model. This model allows direct assessment of the impacts of changes in NSF project budgets on faculty man-years, principal investigators supported, postdoctoral and other nonfaculty personnel supported, graduate students supported, and permanent equipment purchased, by discipline, by institution, or by State. The allocation and impact model is now being improved by refinement of factors for fund distribution by other Federal agencies in order to obtain more accurate estimates of the impact from these sources.

NSF has as a goal the support of research of high quality. Publications and acknowledgements are a measure of quality. It follows that comparisons of the two demonstrate, subject to limitations, the success that NSF has had in pursuing the goal of quality. The evaluation staff has recently finished a draft of a report on use of publications and citations to evaluate the output of research, summarizing and drawing upon work done under a study contract.

Also during fiscal year 1973 a computerized simulation model was developed which ties important variables influencing doctoral scientist supply and demand together in a general structure. With the model it is possible to assess the impacts of alternative policies on the future balance between the supply and demand under varying circumstances.

Four additional studies are now in progress:

- Design of an evaluation of the biomes program of the International Biological Program.
- Development of a "high quality" science resource manpower study with special emphasis on describing the demand function for scientists who received their Ph.D.'s from the top 20 or so graduate schools.
- An analysis of the characteristics of frequently cited papers in science is underway via contract. The objective of the study is to establish a link between high citation frequency and application.
- The achievements and shortcomings of the terminated Science Development Programs are being evaluated under contract with the National Board of Graduate Education of the National Academy of Sciences to determine their worth as models for future programs.

PUBLIC UNDERSTANDING OF SCIENCE

Few thoughtful observers would disagree with the assertion that the rapid progress made by science and technology since World War II has led to many important changes in our standard of living and our quality of life. One resulting problem of this progress, however, has been the increasing complexity of the major issues facing us today which are profoundly influenced by science and technology. The extent to which we can meet and solve these issues may well depend on our ability to achieve a level of public enlightenment on them never before contemplated. If rational and workable policy on these issues is to be carried out with the support of the public, meaningful communications and dialogue between scientific and technical experts and the public must be greatly increased and improved.

The process of improving this dialogue is a complex one involving as it does many "publics," each of which must be reached in different ways and each with its own particular needs for information. These publics include not only the stereotypical "man-on-the-street", but the educational community—teachers and students, government officials at all levels, businessmen, labor leaders, and the communications media itself. The primary purpose of the Public Understanding of Science Program is to encourage meaningful communication and dialogue between scientists and engineers and these various publics on the role and substance of science and technology in helping to meet current and emerging societal problems.

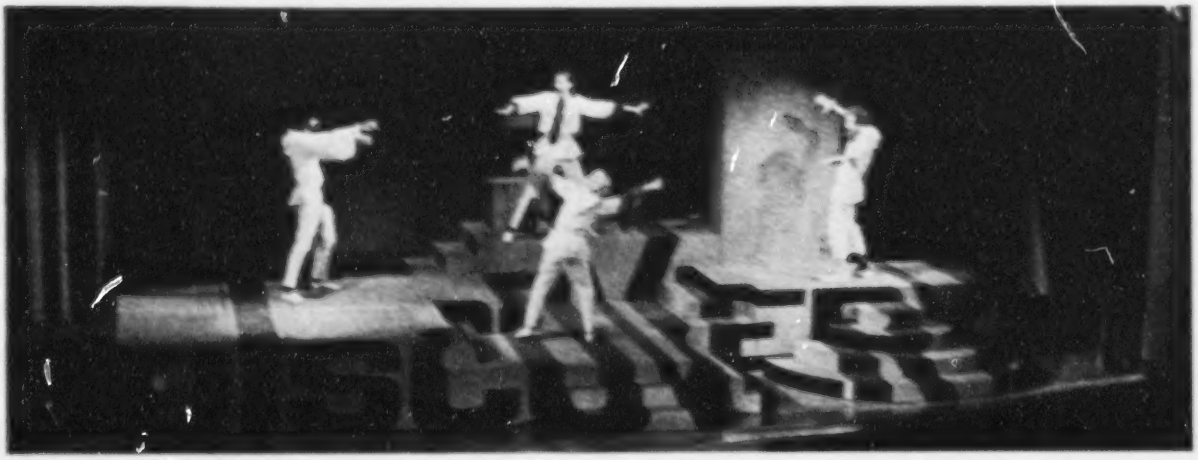
In fiscal year 1973, the Foundation made 21 awards amounting to $810,000 for a variety of public understanding of science projects. At the national level, the American Association for the Advancement of Science (AAAS) received funds to continue their broad-gauged program of seminars, publications, films, and other special projects on and about science. The first in a series of community seminars on the energy dilemma was conducted in

Providence, R.I., by the AAAS in cooperation with the University of Rhode Island. Scientists, government officials, and industry representatives discussed the implications of the national energy dilemma for Rhode Island citizens. Similar seminars in other communities were held during the last half of 1973.

Several projects were supported at the regional and statewide level. In Hawaii the College of Engineering, in cooperation with other groups at the University of Hawaii, conducted a series of conferences on major environmental-related issues of concern to citizens in the State. For example, one such conference dealt with the problem of the public costs of private land development and involved ecologists, developers, and government officials discussing the issues with an audience of citizens, businessmen, and community leaders. Other conferences focused on questions of energy resources, aquaculture, and transportation. The School of Journalism at the University of Missouri, Columbia, sponsored four seminars on science and technology for newspaper editors in Missouri and surrounding States with the express objective of stimulating dialogue between scientists and editors on topics of common interest and concern. The University of Idaho and Washington State University cooperated in the organization and conduct of a conference on the energy crisis for citizens and policymakers in the Pacific Northwest.

Recognizing that television is the most important media in mass communications, the program supported the production of several films on science during the reporting period including a 30-minute documentary on stellar evolution, "The Birth and Death of a Star," produced by the American Institute of Physics and shown nationally on January 29, 1973, over the public television network. The program also provided partial support towards the establishment and initial operation of the Science Programming Group at WGBH-TV Boston. A weekly series of hour-long television shows on science for general audiences is planned by WGBH for broadcast over the national public television system beginning in early 1974.

Two special projects were supported which focus on major upcoming events of particular importance to both scientists and the general public. An award was made to the Spokane International Exposition for the planning and development of a series of seminars on environmental topics as part of EXPO '74, the international exposition on the environment which will open in Spokane in May 1974. Looking ahead towards the 1976 Bicentennial, the University of Arizona sponsored, with program support, a conference of scientists, educators, historians, and media representatives on developing possible themes and programs for interrelating science and technology with the celebration of the Bicentennial. The final report of this conference has been made available to State Bicentennial committees, scientific societies, museums, and other groups as a possible guide in the development of their own Bicentennial programs.



Chicago school children learn about the process of scientific discovery in a specially written play produced jointly by the Chicago Museum of Science and Industry and the Goodman Theatre.

Appendix A

National Science Board, NSF Staff, Advisory Committees and Panels

NATIONAL SCIENCE BOARD

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William A. Fowler, Institute Professor of Physics, California Institute of Technology, Pasadena, Calif.

Norman Hackerman, President, William Marsh Rice University, Houston, Tex.

Philip Handler, President, National Academy of Sciences, Washington, D. C.

James G. March, David Jacks Professor of Higher Education, Political Science, and Sociology, School of Education, Stanford University, Stanford, Calif.

Glenn E. Murray, President, Texas Tech University, Lubbock, Tex.

Frederick E. Smith, Professor of Advanced Environmental Studies in Resources and Ecology, Graduate School of Design, Harvard University, Cambridge, Mass.

Terms Expire May 10, 1976

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Robert A. Charpie, President, Cabot Corporation, Boston, Mass.

Lloyd M. Cooke, Director of Urban Affairs, Union Carbide Corporation, New York, N. Y.

Robert H. Dicke, Cyrus Fogg Brackett Professor of Physics, Department of Physics, Princeton University, Princeton, N. J.

David M. Gates, Professor of Botany and Director, Biological Station, Department of Botany, University of Michigan, Ann Arbor, Mich.

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*Frank Press, Chairman, Department of Earth and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, Mass.

F. P. Thieme, President, University of Colorado, Boulder, Colo.

Terms Expire May 10, 1978

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Anna J. Harrison, Professor of Chemistry, Mount Holyoke College, South Hadley, Mass.

Hubert Heffner, Chairman, Department of Applied Physics, Stanford University, Stanford, Calif.

William H. Meckling, Dean, The Graduate School of Management, the University of Rochester, Rochester, N. Y.

William A. Nierenberg, Director, Scripps Institution of Oceanography, University of California at San Diego, La Jolla, Calif.

*Russell D. O'Neal, Special Assistant to the Chief Executive Officer, The Bendix Corporation, Southfield, Mich.

Joseph M. Reynolds, Boyd Professor of Physics and Vice President for Instruction and Research, Louisiana State University, Baton Rouge, La.

Member Ex Officio

*H. Guyford Stever, Director, National Science Foundation, Washington, D.C. (Chairman, Executive Committee)

Vernice Anderson, Executive Secretary, National Science Board, National Science Foundation, Washington, D.C.

*Member, Executive Committee

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National Bureau of Standards

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John E. Hopcroft
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National Science Foundation

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NATIONAL AND INTERNATIONAL PROGRAMS

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University of California, San Diego

William J. Hargis, Jr.
Virginia Institute of Marine Sciences

Feman D. Jennings (Chairman)
International Decade of Ocean
Exploration Program
National Science Foundation

Francis L. LaQue
Vero[illegible]

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The University of Connecticut

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Food and Agriculture Organization
of the United Nations
Rome, Italy

Arthur E. Maxwell
Woods Hole Oceanographic Institution

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William W. Rand
Kensington, Calif.

John H. Ryther
Woods Hole Oceanographic Institution

Edward C. Stephan
Washington, D.C.

International Decade of Ocean Exploration Proposal Review Panel

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University of California, San Diego

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Lamont-Doherty Geological Observatory

Donald W. Hood
Institute of Marine Sciences
University of Alaska

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International Decade of Ocean
Exploration Program
National Science Foundation

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Marine Geology & Geophysics
Laboratory, NOAA
Miami, Fla.

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Office of Naval Research
London, England

Joseph Reid
Scripps Institution of Oceanography
University of California, San Diego

Peter Tarro, CDR, USN
Office of Naval Research
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National Science Foundation

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City University of New York

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Linda Wilson
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Washington University

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Raymond Woodrow
University Research Board
Princeton University

Science Information Council

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Harvard Business School

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Lincoln University

Lee G. Burchinal
Head, Office of Science Information Service
National Science Foundation

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Director (Acting)
National Agricultural Library

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Purdue University

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University of Maryland

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EDUCATION

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O. Meredith Wilson
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Stanford, Calif.

Appendix B

Organization Changes and Appointments

Office of the Director

The following staff changes occurred in the immediate office of the Director. Theodore D. Drury, from the Office of Government and Public Programs to Special Assistant to the Director. Donald E. Cunningham, formerly head, Experimental Design and Evaluation Staff, Office of Experimental R&D Incentives, to Special Assistant to the Deputy Director.

The following activities were organized, reporting to the Office of the Director:

Office of Experimental R&D Incentives

The Office of Experimental R&D Incentives, in August 1972, responsible for providing incentives for encouraging increased investment in research and development by the civilian sector and improving and accelerating the application of R&D results.

Office of [illegible] Assessment

The Office of National R&D Assessment, in August 1972, responsible for providing an assessment capability to better understand research and development and innovative processes, and the impact of science and technology on the various elements of economy and on society.

NSF Energy R&D Task Force

An NSF Energy R&D Task Force, in April 1973, to provide a detailed proposal for the development of a comprehensive national program for the conduct of energy-related research and development, with special emphasis on the long-term Federal role in furthering and coordinating energy research and development, and on overall environmental, conservation, and policy issues.

Ethical and Human Value Implications Program

An Ethical and Human Value Implications of Science and Technology Program, in February 1973, in support of scholarly activities relating to ethical and human value implications of science and technology. This program will operate in collaboration with a similar program of the National Endowment for the Humanities.

Assistant Director for Education

The Computer Innovations in Education Section of the Office of Computing Activities was transferred from the National and International Programs Directorate to the Education Directorate, in October 1972.

The Education Directorate was reorganized in January 1973, to give new direction to the mission of the Foundation's science education program.

Assistant Director for Research

The Division of Engineering was reorganized in July 1972.

Assistant Director for National and International Programs

The Research Management Improvement Program was established in August 1972.

The Computer Impact on Society Section was established in the Office of Computing Activities in November 1972.

The special foreign currency activities of the Office of Science Information Service were transferred to the Office of International Programs in June 1973 and designated the Special Foreign Currency Section.

The Office of Science Information Service was reorganized in June 1973.

Assistant Director for Research Applications

The Office of Programs and Resources was established in July 1972, replacing the Management Support Staff.

The Office of Intergovernmental Science and Research Utilization was established in July 1972, replacing the Office of Intergovernmental Science Programs.

The Office of Public Technology Projects was established in November 1972.

Assistant Director for Administration

In August 1972, the Management Information Project Office was combined with the Data Management Systems Office to form the Management Information Office. In May 1973, the new office was reorganized.

The Administrative Services Office was reorganized in March 1973.

Staff Changes

In addition to the appointments mentioned above, the following key staff appointments were announced during the year.

C. Bronson Smith, Director, Office of Experimental R&D Incentives
Leonard L. Lederman, Director, Office of National R&D Assessment
Paul F. Donovan, Chairman, NSF Energy R&D Task Force
Charles F. Brown, General Counsel
Maryann B. Lloyd, Deputy General Counsel
Theodore W. Wirths, Director, Office of Government and Public Programs
Patricia E. Nicely, Head, Congressional Liaison Office
Alfred E. Rosenthal, Head, Public Affairs Office
Thomas E. Jenkins, Assistant Director for Administration
Wilbur W. Bolton, Jr., Administrative Manager
Eldon D. Taylor, Deputy Assistant Director for Administration
Jack T. Sanderson, Head, Office of Budget, Programming, and Planning Analysis
Syl McNinch, Jr., Deputy Head, Office of Budget, Programming, and Planning Analysis

Wayne A. Grunet, Assistant to the Assistant Director for Research
Eloise E. Clark, Director, Division of Biological and Medical Sciences
Howard J. Hausman, Director, Division of Pre-College Education in Science
Francis G. O'Brien, Director, Division of Higher Education in Science
Lyle W. Phillips, Head, Office of Experimental Projects and Programs
Lee G. Burchinal, Head, Office of Science Information Services
William H. Wetmore, Director, Office of Systems Integration and Analysis
Holt Ashley, Director, Exploratory Research and Problem Assessment
T. W. Aiken, Director, Office of Programs and Resources
John B. Talmadge, reassigned from Head, Congressional Liaison Office to Deputy Director, Office of Programs and Resources.

Resignations

Melvin Day, Head, Office of Science Information Services, left the Foundation to accept a position at the National Library of Medicine.
Harold W. Paxton, Director, Division of Materials Research, left the Foundation and returned to Carnegie-Mellon University.
Robert F. Wilcox, Head, Public Understanding of Science Office, left the Foundation to accept a position at the University of Colorado.
Lawton W. Hartman, Special Assistant to the Director.

Retirements

William V. Consolazio, Special Assistant to the Director
William J. Hoff, General Counsel
Clarence C. Ohlke, Director, Office of Government and Public Programs
Harve J. Carlson, Director, Division of Biological and Medical Sciences
Edward R. Trapnell, Deputy Director, Office of Government and Public Programs
Howard D. Kramer, Director, Division of Graduate Education in Science
Thomas J. Mills, Director, Division of Science Resources Studies
Charles A. Whitmer, Director, Division of Pre-College Education in Science

Changes in the National Science Board

The following were appointed to the National Science Board: Dr. W. Glenn Campbell (Director, Hoover Institution on War, Revolution, and Peace, Stanford University); Dr. T. Marshall Hahn, Jr. (President, Virginia Polytechnic Institute and State University); Dr. Anna J. Harrison (Professor of Chemistry, Mount Holyoke College); Dr. Hubert Heffner (Chairman, Department of Applied Physics, Stanford University); Mr. William H. Meckling (Dean, The Graduate School of Management, The University of Rochester); Dr. William A. Nierenberg (Director, Scripps Institution of Oceanography, University of California, San Diego); and Dr. Russell D. O'Neal (Special Assistant to the Chief Executive Officer, The Bendix Corporation, Southfield, Mich.).

Appendix C Financial Report for Fiscal Year 1973

Salaries and Expenses Appropriation		
Fund Availability		
Fiscal year 1973 appropriation	$638,740,000	
Unobligated balance carried forward from fiscal year 1972	31,838,743	
Transfer to GSA for rent	−255,015	
Fiscal year 1973 availability		$670,323,728
Net Obligations		
Scientific research project support:		
Atmospheric sciences	$11,927,869	
Earth sciences	9,763,409	
Oceanography	12,662,053	
Biological sciences	56,270,845	
Physics	34,883,571	
Chemistry	25,081,400	
Astronomy	8,794,164	
Mathematical sciences	14,063,658	
Social sciences	23,633,285	
Engineering	76,156,678	
Materials research	34,973,251	
Computing activities	9,895,322	
Subtotal, scientific research project support		$268,057,506
National and special research programs:		
International biological program	$9,194,858	
Global atmospheric research program	3,445,122	
Experimental R&D incentives program	11,889,586	
National R&D assessment program	2,291,268	
International decade of ocean exploration	16,934,313	
Ocean sediment coring program	9,594,106	
Arctic research program	3,434,681	
U.S. Antarctic research program	44,004,243	
Oceanographic facilities and support	10,993,719	
Tokar eclipse support	681,821	
Subtotal, national and special research programs		$112,463,727
National research centers:		
National Astronomy and Ionosphere Center	$3,250,000	
Kitt Peak National Observatory	7,850,000	
Cerro Tololo Inter-American Observatory	2,700,000	
National Radio Astronomy Observatory	9,950,000	
National Center for Atmospheric Research	16,000,000	
Subtotal, national research centers		$39,750,000
Science information activities	$8,464,408	
International cooperative scientific activities	4,663,306	
Research applied to national needs:		
Advanced technology applications	$14,708,796	
Advanced energy research and technology	14,229,027	
Environmental systems and resources	22,502,434	
Social systems and human resources	13,352,323	
Exploratory research and problem assessment	5,094,734	
Subtotal, research applied to national needs		$69,887,314
Intergovernmental science and research utilization	$ 997,733	
Institutional improvement for science	9,101,767	
Graduate student support	15,308,895	
Science education improvement	46,924,510	
Planning and policy studies	1,689,870	
Program development and management	28,619,198	
Subtotal		$605,928,234
Unobligated balance carried forward to fiscal year 1974		64,395,494
Total		$670,323,728
Scientific Activities (Special Foreign Currency) Appropriation		
Fund Availability		
Fiscal year 1973 appropriation	$7,000,000	
Net Obligations		
Total obligations for fiscal year 1973		$4,342,121
Unobligated balance carried forward to fiscal year 1974		2,657,879
Total		$7,000,000
Trust Fund		
Fund Availability		
Unobligated balance brought forward from fiscal year 1972		$5,159
Donations from private sources		620
Total availability		5,779
Net Obligations		
Total availability		$5,779
Less unobligated balance carried forward to fiscal year 1974		6,785
Total obligations		−1,006

Appendix D

Patents Resulting from Activities Supported by the National Science Foundation

The Foundation, since its last annual report, has received notification of the issuance of the following two patents by the U.S. Patent Office covering inventions arising out of Foundation-supported activities on each of which the U.S. Government has received a non-exclusive, irrevocable, nontransferable, paid-up, worldwide license:

Patent No. 3,733,050 entitled "High Pressure Valve" was issued on May 15, 1973, on an invention made by Peter R. Gordon in the course of research supported by a grant to Stanford University. The invention is a high pressure valve in which the valve needle is guided in a well formed in the valve body so that it can be moved to seat one end in a valve seat formed at the bottom of said well.

Patent No. 3,742,212 entitled "Method and Apparatus for Pulsed Ion Cyclotron Resonance Spectroscopy" was issued on June 26, 1973, on an invention made by Robert T. McIver, Jr., in the course of research supported by a grant to Stanford University. The invention is a method and apparatus for pulsed ion cyclotron resonance spectroscopy in which a gas sample within an analyzer cell is ionized by means such as a pulse of an electron beam, the ions then being trapped and caused to move orbitally within the cell by the combined action of static electric fields and a magnetic field.

Appendix E

Publications of the National Science Foundation, Fiscal Year 1973

1 International Decade of Ocean Exploration, A Guide to the Preparation of Proposals (NSF 72-17)
2 Scientists and Engineers in Economic Development Program (NSF 72-18)
3 Report of Awards, 1971-72, Division of Environmental Systems and Resources (NSF 72-19)
4 *Mosaic*, Vol. 3, No. 3 (NSF 72-20)
5 Engineering Research Initiation Grants, 1973 (NSF 72-21)
6 Student-Originated Studies Proceedings, 1971 (NSF 72-22)
7 National Science Foundation Guide to Programs, Fiscal Year 1973 (NSF 72-23)
8 Public Understanding of Science Program, Guidelines for the Preparation of Proposals (NSF 72-24)
9 *Mosaic*, Vol. 3, No. 4 (NSF 72-25)
10 Experimental R&D Incentives Program Announcement (NSF 72-26)
11 The National Science Board (NSF 72-27)
12 National Science Foundation Research Applied to National Needs: the Division of Environmental Systems and Resources (NSF 72-28)
13 Report of Awards, Fiscal Year 1972, Division of Social Systems and Human Resources (NSF 72-29)
14 Scientists, Engineers, and Physicians from Abroad, Trends Through Fiscal Year 1970 (NSF 72-312)
15 An Analysis of Federal R&D Funding by Function, Fiscal Years 1963-73 (NSF 72-313)
16 Science Resouces Studies Highlights: "Federal R&D Funding Continues to Rise" (NSF 72-314)
17 Resources for Scientific Activities at Universities and Colleges, 1971 (NSF 72-315)
18 Science Resources Studies Highlights: "Federal Support to Universities and Colleges Reaches $3.5 Billion in Fiscal Year 1971" (NSF 72-316)
19 Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1971, 1972, and 1973, Vol. XXI (NSF 72-317)
20 Science Resources Studies Highlights: "Company Funds Push Total Industrial R&D Spending to $18 Billion in 1971" (NSF 72-318)
21 Science Indicators, 1972 (NSB 73-1)
22 Twenty-Second Annual Report, 1972, National Science Foundation (NSF 73-1)
23 Grants and Awards, 1972, National Science Foundation (NSF 73-2)
24 National Science Foundation Databook (NSF 73-3)
25 Evaluation of Policy-Related Research in the Field of Municipal Systems, Operations, and Services (NSF 73-4)
26 *Mosaic*, Vol. 4, No. 1 (NSF 73-5)
27 National Science Foundation (General Information Brochure) (NSF 73-6)
28 Evaluation of Policy-Related Research in the Field of Human Resources (NSF 73-7)
29 Exploratory Technology Assessments in Selected Areas (NSF 73-8)
30 Publications of the National Science Foundation, May 1973 (NSF 73-9)
31 *Mosaic*, Vol. 4, No. 2 (NSF 73-10)
32 Office of Exploratory Research and Problem Assessment (NSF 73-11)
33 Grants for Scientific Research (NSF 73-12)
34 Grants for Computing Activities (NSF 73-13)
35 Federal Support to Universities, Colleges, and Selected Nonprofit Institutions, Fiscal Year 1971 (NSF 73-300)
36 Science Resources Studies Highlights: "NSF Forecasts Rise in Company-Funded Research and Development and R&D Employment" (NSF 73-301)
37 Immigrant Scientists and Engineers in the United States: A Study of Characteristics and Attitudes (NSF 73-302)
38 National Patterns of R&D Resources, Funds and Manpower in the United States (NSF 73-303)
39 Graduate Student Support and Manpower Resources in Graduate Science Education, Fall 1971 (NSF 73-304)
40 Research and Development in Industry, 1971, Funds, 1971, Scientists and Engineers, January 1972 (NSF 73-305)
41 Initial Reports of the Deep Sea Drilling Project, Vol. 12 (NSFSP-12)
42 Initial Reports of the Deep Sea Drilling Project, Vol. 13 (NSFSP-13)
43 Initial Reports of the Deep Sea Drilling Project, Vol. 14 (NSFSP-14)

Appendix F

National Research Centers Contractors

Associated Universities, Inc. (AUI)
Gerald F. Tape, President

National Radio Astronomy Observatory
David S. Heeschen, Director

AUI Member Universities:
Columbia University
Cornell University
Harvard University
The Johns Hopkins University
Massachusetts Institute of Technology
University of Pennsylvania
Princeton University
University of Rochester
Yale University

Association of Universities for Research in Astronomy, Inc. AURA)
Gilbert Lee, President

Cerro Tololo Inter-American Observatory
Victor M. Blanco, Director
Kitt Peak National Observatory
Leo Goldberg, Director

AURA Member Universities:
University of Arizona
California Institute of Technology
University of California
University of Chicago
Harvard University
Indiana University
University of Michigan
Ohio State University
Princeton University
University of Texas at Austin
University of Wisconsin
Yale University

Cornell University
W. Donald Cooke, Vice President for Research

National Astronomy and Ionosphere Center
Frank D. Drake, Director, Ithaca, n.Y.
Harold D. Craft, Director, Observatory Operations, Arecibo, Puerto Rico

University Corporation for Atmospheric Research (UCAR)
Walter Orr Roberts, President

National Center for Atmospheric Research
John W. Firor, Director

UCAR Member Universities:
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University of Arizona
California Institute of Technology
University of California
The Catholic University of America
University of Chicago
Colorado State University
University of Colorado
Cornell University
University of Denver
Florida State University
Harvard University
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The Johns Hopkins University
University of Illinois at Urbana—Champaign
University of Maryland
Massachusetts Institute of Technology
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University of Miami
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Oregon State University
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The Rice University
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University of Toronto
Utah State University
University of Utah
University of Washington
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